resourceful. naturally.
engineering and environmental consultants
BARR

Memorandum

To: MIDS Work Group
From: Barr Engineering Company
Subject: Item 1: Vegetation and Soils
Date: December 17, 2010
Project: 23621050 MIDS

The intent of this memorandum is to summarize the review of readily available data sources related to natural vegetation and soil types in Minnesota, and the systems developed and used to classify and describe the landscape level aggregations of characteristics. The intent was not to create new information, but rather prepare a compilation of existing data. As such, much of the information provided is excerpted from existing documents. Appropriate citations are provided and, where needed, context is provided.

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

While soils and landscape characteristics are important in defining these classifications systems, the native vegetation is a critical aspect of the pre-settlement (pre-development) runoff patterns from any landscape. A short discussion of the interactions of native plant communities and landscape hydrology (and nutrient loadings) is included in an attempt to add more context to the use of these systems.

Summary Descriptions of Classification Systems

There are several national and state classifications systems. The following sections discuss five national classification systems and eight state or national subset systems. A summary comparison of the systems discussed is presented in Table 1. Land cover and soils are factors common to all of the systems reviewed.

Table 1. Classification Systems – Summary of Characteristics

System Name	Developer[1]	Intent/Purpose of System	Classes/Number in Minnesota	Classification Factors
Ecoregions of the United States	USDA/ USEPA	General description of ecosystem geography	Three provinces	Land-surface form and soils, climate and vegetation
Omernik Level III Ecoregions	CEC/USEPA	Intended for regional environmental monitoring, assessment and reporting as well as decision-making uses	Seven Ecoregions	Land-surface form and soils, climate and vegetation
Level III National Aggregate Nutrient Ecoregions	USEPA	Used in nutrient and ambient water quality criteria	Three Aggregate Ecoregions	Land cover and agricultural uses
Major Land Resources Areas of Minnesota	USDA/ NRCS	Statewide agricultural planning	15 Land Resource Areas	Physiography, geology, climate, water, soils, biological resources, land use patterns
Regional Landscape Ecosystems (Kuchler Vegetation types)	USDA - FS	Create a map of the potential natural vegetation	28 Sub-subsections	Climate, bedrock geology, glacial landform, soils
Marschner Map of "Pre-Settlement" Vegetation	USDA - FS and U of MN	Mapping of pre-settlement vegetation.	17 Vegetation Types	General Land Office surveyors notes for tree species and their diameters
Ecological Land Classification Hierarchy	MN DNR and USDA - FS	Describe, and map areas of uniform ecological features	Four Provinces; Ten Sections; 26 Subsections; 291 Land Type Associations	Climate, geology, topography, soils, hydrology, vegetation
Minnesota Ecoregions	MPCA	General description of ecosystem geography	Seven Level III Ecoregions; 31 Level IV Ecoregions	Land-surface form and soils, climate and vegetation
Minnesota Agroecoregions	U of MN and MDA	Landscape level framework for agricultural BMPs	29 Agroecoregions	Precipitation, soil geomorphology, slope steepness, soil internal drainage, crop productivity
Soils and Land Surfaces of Minnesota	U of MN - Agricultural Experiment Station	Delineation of major soil areas within the state	Multiple Levels and Classes; 18 Soil Textures Families presented in Figure 11	Geologic origin, climate, landscape properties, potential biotic communities, length of interaction (time)
Minnesota Soil Survey	USDA - NRCS	Soil mapping	Multiple Levels and Classes within the OSD; Twelve major Order presented in Figure 13	Soil genesis, soil properties, and relief

1 Abbreviations

USDA: United States Department of Agriculture
USEPA: United States Environmental Protection Agency
CEC: Commission for Environmental Cooperation Working Group
NRCS: Natural Resources Conservation Services (formerly Soil Conservation Service, SCS)
FS: Forest Service
U of MN: University of Minnesota
MN DNR: Minnesota Department of Natural Resources
MDA: Minnesota Department of Agriculture
OSD: Official Soil Series Description

National Level Systems

Ecoregions are defined as regions of relative homogeneity in ecological systems, such that geographic characteristics like soils, vegetation, climate, geology, and land cover are relatively similar within the bounds of each ecoregion (Omernik, 2000). Omernik (1987) recognized that areas of the United States have naturally different soil and parent material nutrient content as well as different precipitation regimes. Based upon these distinct patterns, the application of sorting criteria allowed for the development of a scheme of ecological regions that reflect this regional variation. The ecoregional approach was initially completed for the continental United States and has been used for regional water quality assessment and plant community management strategies in the United States, Canada, and by a number of international conservation organizations (Omernik, 1995). The continental United States was divided into 14 separate Level III aquatic ecoregions for the purpose of aquatic resource investigation and management (Omernik, 1977a: Omernik, 1977).

The United States Environmental Protection Agency (EPA) has developed generalized “nutrient Ecoregions” that are aggregations of the Level III Ecoregions (EPA 2000d, EPA 2000e). Within Minnesota there are seven Level III ecoregions and the use of the EPA Level III Aggregate Ecoregions reduces the number to three.

Name of System: Ecoregions of the United States

Citation: Bailey, R. G. 1976. Ecoregions of the United States (map). Ogden, Utah: USDA Forest Service, Intermountain Region. 1:7,500,000.

Figure # and name: Figure 1. Ecosytem Provinces (Bailey, 1995).

Description of system:

This was originally published in 1978 to provide a general description of the ecosystem geography of the Nation as shown on the 1976 map "Ecoregions of the United States." It was first published as an unnumbered publication by the Intermountain Region, USDA Forest Service, Ogden, Utah. It was reprinted in 1980 by the Forest Service, Washington, DC, as Miscellaneous Publication No.1391. An explanation of the basis for the regions delineated on the map was presented elsewhere (Bailey 1983). The goal in preparing this edition, like its predecessor, was not to present information, but to strive for synthesis, i.e., the illustration of interrelationships. The interrelationships of land-surface form and soils, climate and vegetation were recognized as important to the development of ecosystems; these were the primary factors used in development of the mapping scheme.

Minnesota has three provinces under the Bailey scheme:

1. Laurentian Mixed Forest Province – Northern and northeast Minnesota
2. Eastern Broadleaf Forest (Continental) Province - Southeast Minnesota
3. Prairie Parkland (Temperate) Province – Western Minnesota

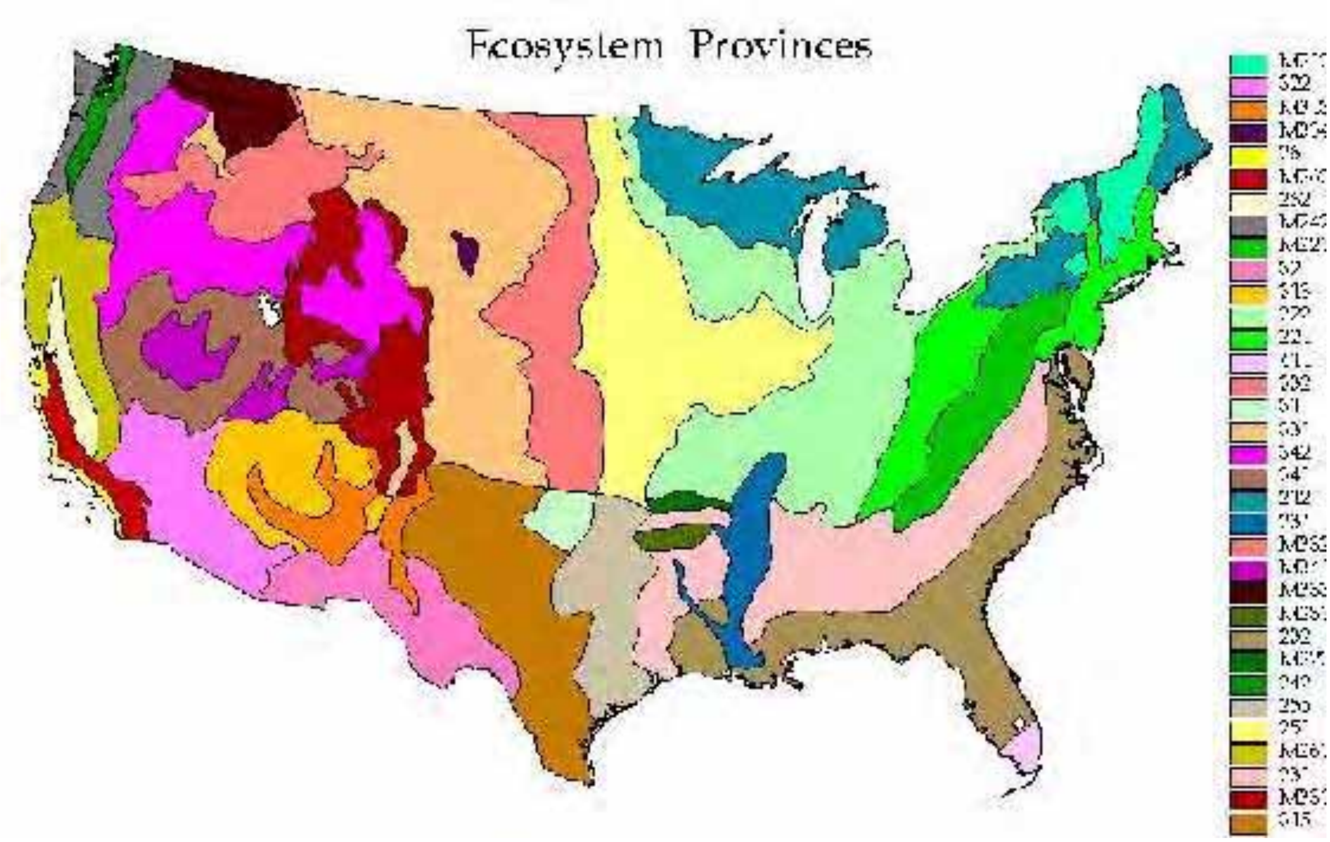


Figure 1. Ecosystem Provinces (Bailey, 1995).

Name of System: Omernik Level III Ecoregions

Citation: Omernik, James M., 1995. Ecoregions: A spatial framework for environmental management. In: Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Davis, W.S. and T.P. Simon (eds.) Lewis Publishers, Boca Raton, FL. Pp. 49-62.

Figure # and name: Figure 2. Major Basins with EPA Level III Ecoregions

Description of system:

Maps and descriptions for the ecological regions of the United States have been developed by the Commission for Environmental Cooperation Working Group (CEC), a joint United States, Mexico, and Canada collaboration, and by James Omernik and colleagues at the United States EPA, along with a large team of collaborators at many federal, state and local agencies. Ecoregions are organized by four increasingly finer geographic scales. The Level I scale divides North America into 15 broad ecological regions. Fifty-two Level II ecological regions for North America provide a more detailed description of the large ecological areas nested within the Level I regions. About 200 Level III ecological regions are delineated that provide a more detailed description of the large ecological areas nested within the Level II regions for the United States**.** Level IV ecoregions are defined for individual states.

About 200 Level III ecological regions are delineated that provide a more detailed description of the large ecological areas nested within the Level II regions. These smaller divisions are intended enhance regional environmental monitoring, assessment and reporting as well as decision-making. Because Level III regions are smaller, they allow locally defining characteristics to be identified, and more specifically oriented management strategies to be formulated.

Ecoregions have been defined for all 50 states. The ecoregions shown in Figure 2 were derived from Omernik (1987) and from refinements of Omernik's framework that have been made for other projects. These ongoing or recently completed projects, conducted in collaboration with the United States EPA regional offices, state resource management agencies, and with other federal agencies, involve refining ecoregions, defining subregions, and locating sets of reference sites.

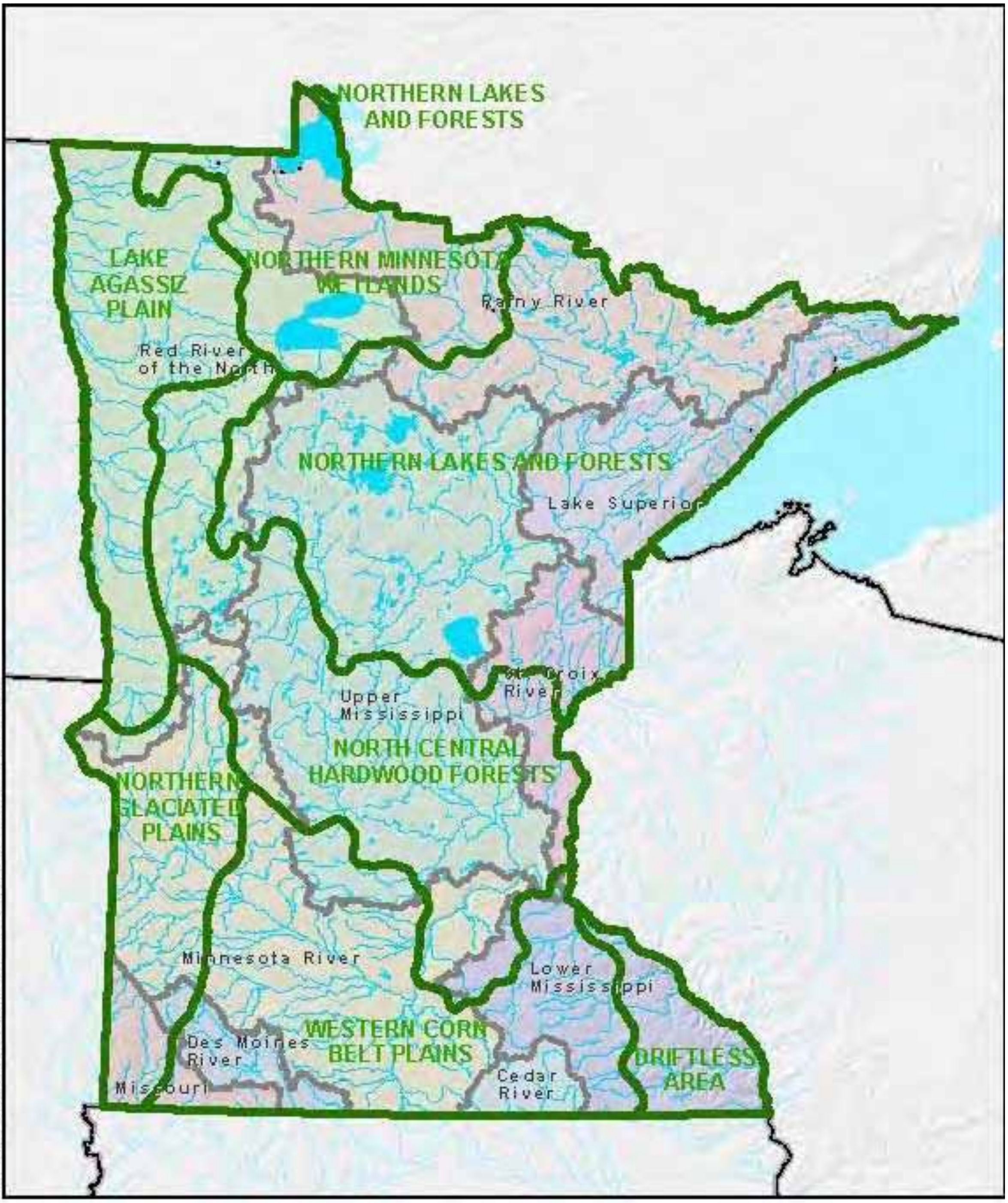


Figure 2. Major Basins with EPA Level III Ecoregions

Name of System: Level III National Aggregate Nutrient Ecoregions

Citation: Omernik, James M., 1995. Ecoregions: A spatial framework for environmental management. In: Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Davis, W.S. and T.P. Simon (eds.) Lewis Publishers, Boca Raton, FL. Pp. 49-62.

Figure # and name: Figure 3. Level III National Aggregate Nutrient Ecoregions

Description of system:

The United States EPA has developed generalized "nutrient Ecoregions" that are aggregations of the Level III Ecoregions (EPA 2000a, EPA 2000b). Within Minnesota there are seven Level III ecoregions and the use of the EPA Level III Aggregate Ecoregions reduces the number to three (see Figure 1 and 2). As the number of phosphorus export studies completed in Minnesota is relatively small, the use of export rates from the larger Level III aggregate regions provides a wider data set that can be extrapolated across the basins (MPCA, 2004).

The United States EPA acknowledges that the Aggregate Level III ecoregions have a higher degree of variability because of the lumping, but the Level III ecoregions are useful for setting nutrient criteria. Recent EPA guidance for development of ambient water quality criteria for lakes, stream, and reservoirs has proposed the use of the Level III ecoregional framework by states and tribes.

The three aggregate Level III ecoregions included in this assessment are (see Figure 3):

- VI - Corn Belt and Northern Great Plains
- VII - Mostly Glaciated Dairy Region
- VIII - Nutrient Poor Largely Glaciated Upper Midwest and Northeast

The Level III National Aggregate Nutrient Ecoregions align with the Bailey (1995) Ecosystem Provinces, but have been used to assess nutrient impacts based upon land cover and agricultural uses.

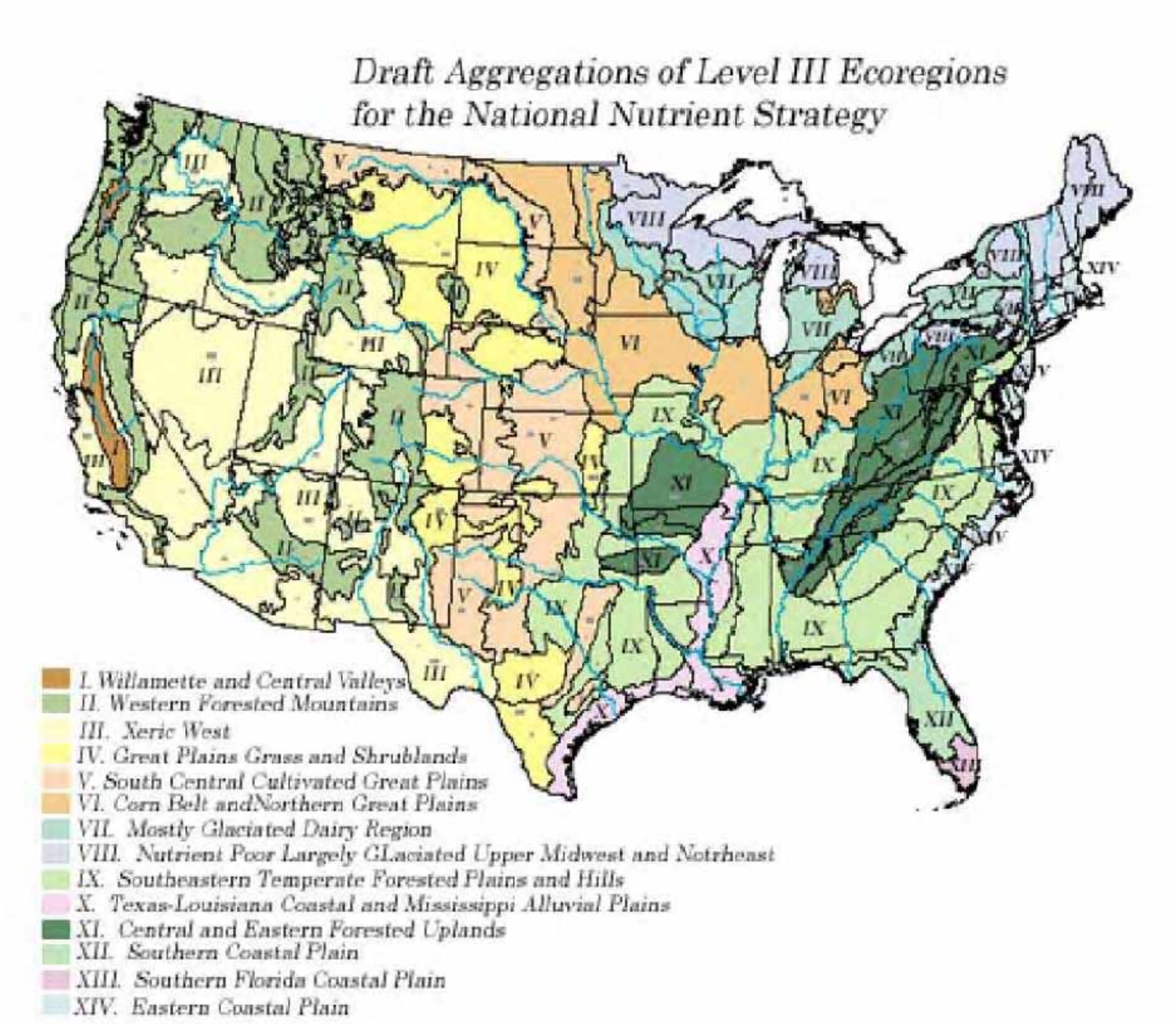


Figure 3. Level III National Aggregate Nutrient Ecoregions

Name of System: Major Land Resources Areas of Minnesota

Citation: United States Department of Agriculture. 2006. Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Agricultural Handbook 296, USDA, NRCS. Accessed at http://soils.usda.gov/survey/geography/mlra/

Figure # and name: Figure 4. Major Land Resources Areas of Minnesota (2008)

Description of system:

Major land resource areas (MLRAs) are geographically associated land resource units (LRUs). Identification of these large areas is important in statewide agricultural planning and has value in interstate, regional, and national planning.

The 278 major land resource areas are designated by Arabic numbers and identified by a descriptive geographic name in Agriculture Handbook 296. For example, MLRA 105 (Northern Mississippi Valley Loess Hills) is in far southeast Minnesota; MLRA 92 (Superior Lake Plain) is on the shores of Lake Superior; and MLRA 57 (Northern Minnesota Gray Drift) is in the central lakes area surrounding Bemidji. Where preexisting MLRAs have been revised, an alphabetic suffix is often added to the original Arabic number (e.g., MLRA 102A, MLRA 102B, and MLRA 102C).

The dominant physical characteristics of the major land resource areas are described briefly in Agriculture Handbook 296. The physiography, geology, climate, water, soils, biological resources, and land use patterns are described for MRLA.

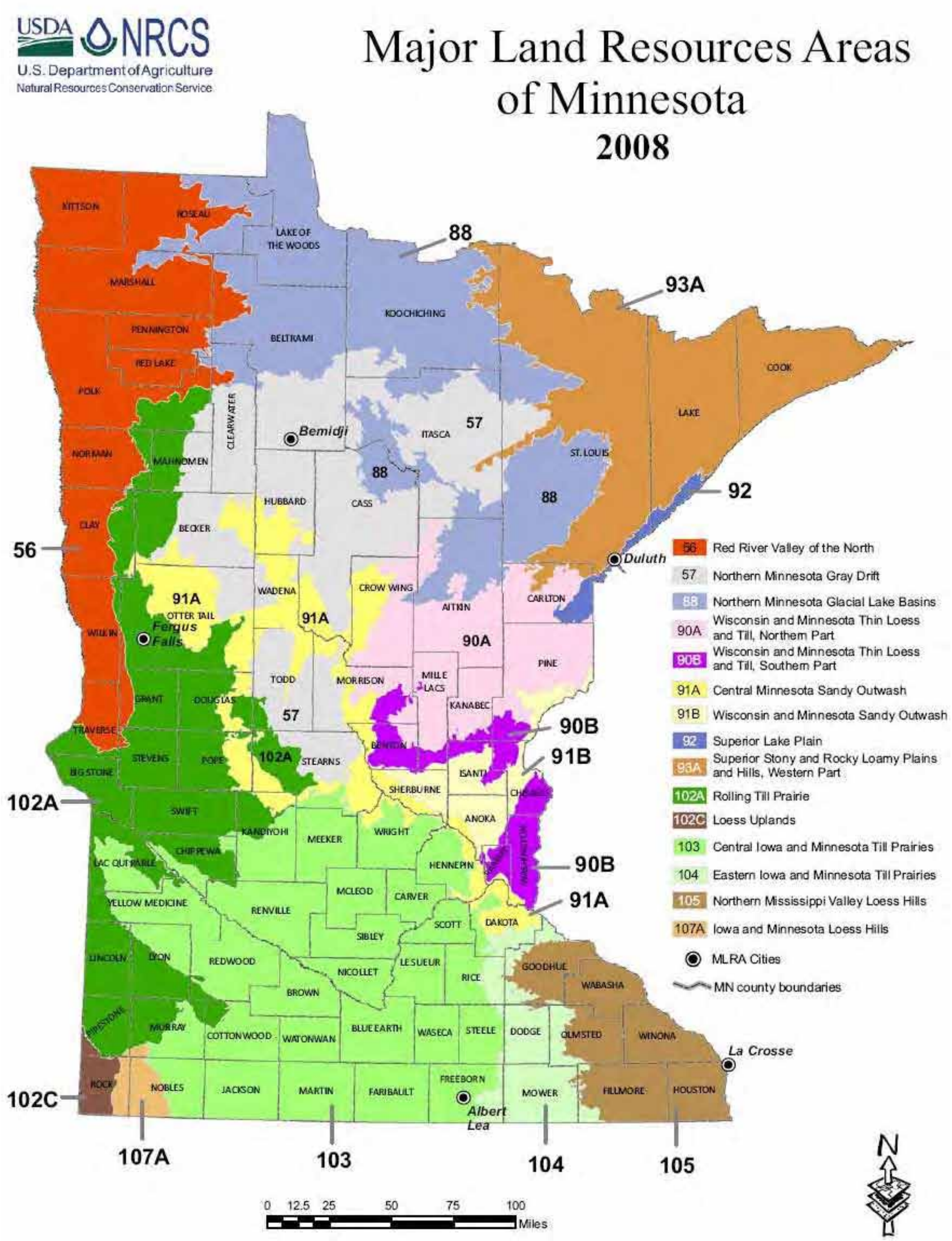


Figure 4. Major Land Resources Areas of Minnesota (2008)

Name of System: Regional Landscape Ecosystems

Citation: Albert, Dennis A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: a working map and classification. Gen. Tech. Rep. NC-178. St. Paul, MN: United States Department of Agriculture, Forest Service, North Central Forest Experiment Station. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/habitat/rlandscp/index.htm (Version 03JUN1998).

Figure # and name: Figure 5. Regional Landscape Ecosystems of Minnesota

Description of system:

This system, often referred to as the Kuchler vegetation types provides a regional landscape ecosystem classification for Michigan, Wisconsin, and Minnesota. In the 1960s, Dr. Kuchler developed the classification system for types of vegetation that would cover the land if there were no disturbances from man or nature. Kuchler (1975) applied this system to create a map of the potential natural vegetation of the continental United States. The classification system was adopted as the base for university and government sponsored research and program development. Although other models derived from climate, biomes, ecoregions, and life zones have been developed, the terms for Kuchler vegetation types are commonly used.

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-sections. Vegetation was used wherever possible to validate climatic and geomorphologic boundaries. Further, by drawing on the expertise of numerous members of the scientific and conservation communities, specific information was incorporated 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.

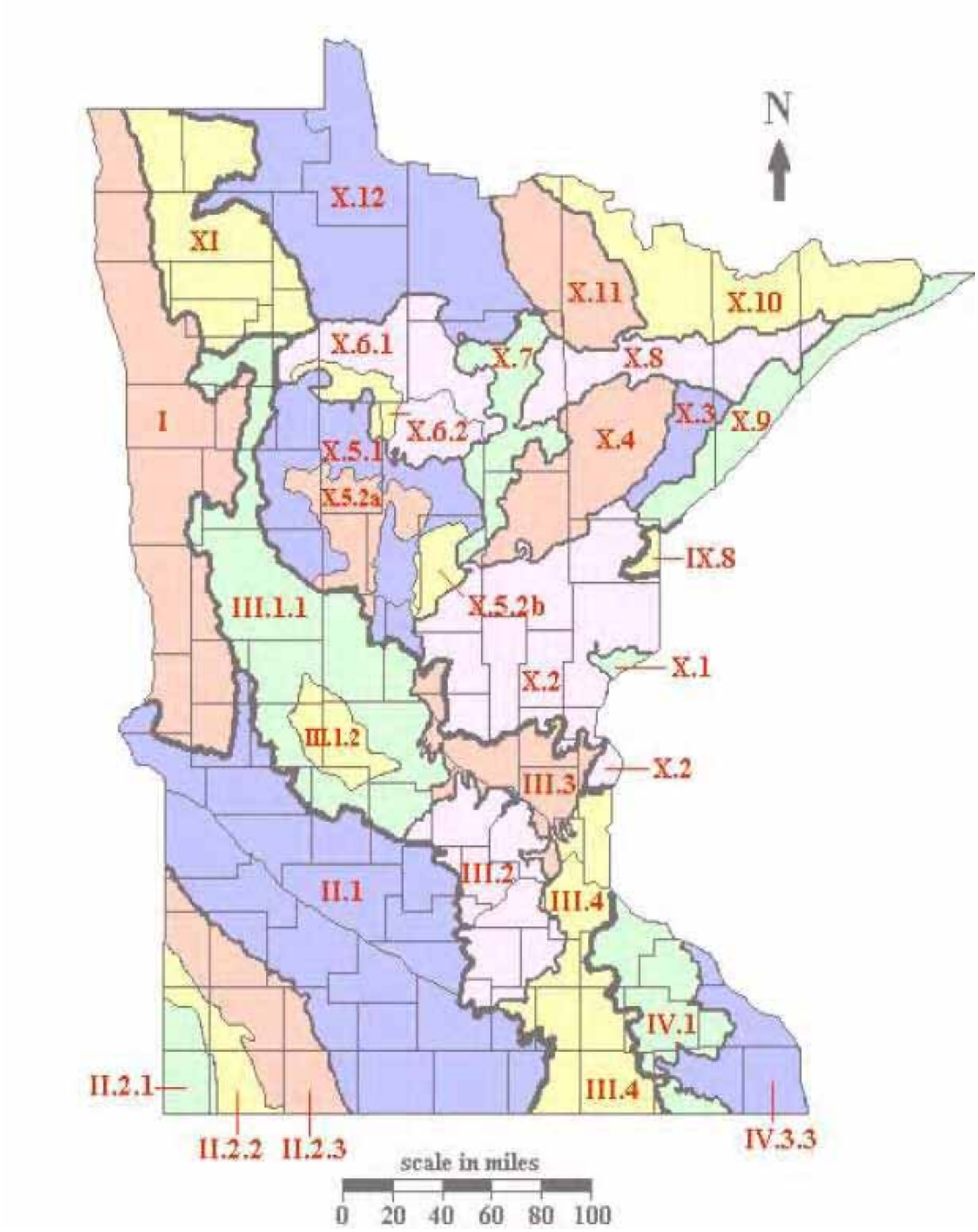


Figure 5. Regional Landscape Ecosystems of Minnesota

State Level

A number of landscape or ecosystem classifications and mapping systems have been developed for Minnesota. In most cases, these are based upon a national, or sometimes even an international classification and mapping system that has been applied to Minnesota for some specific purpose.

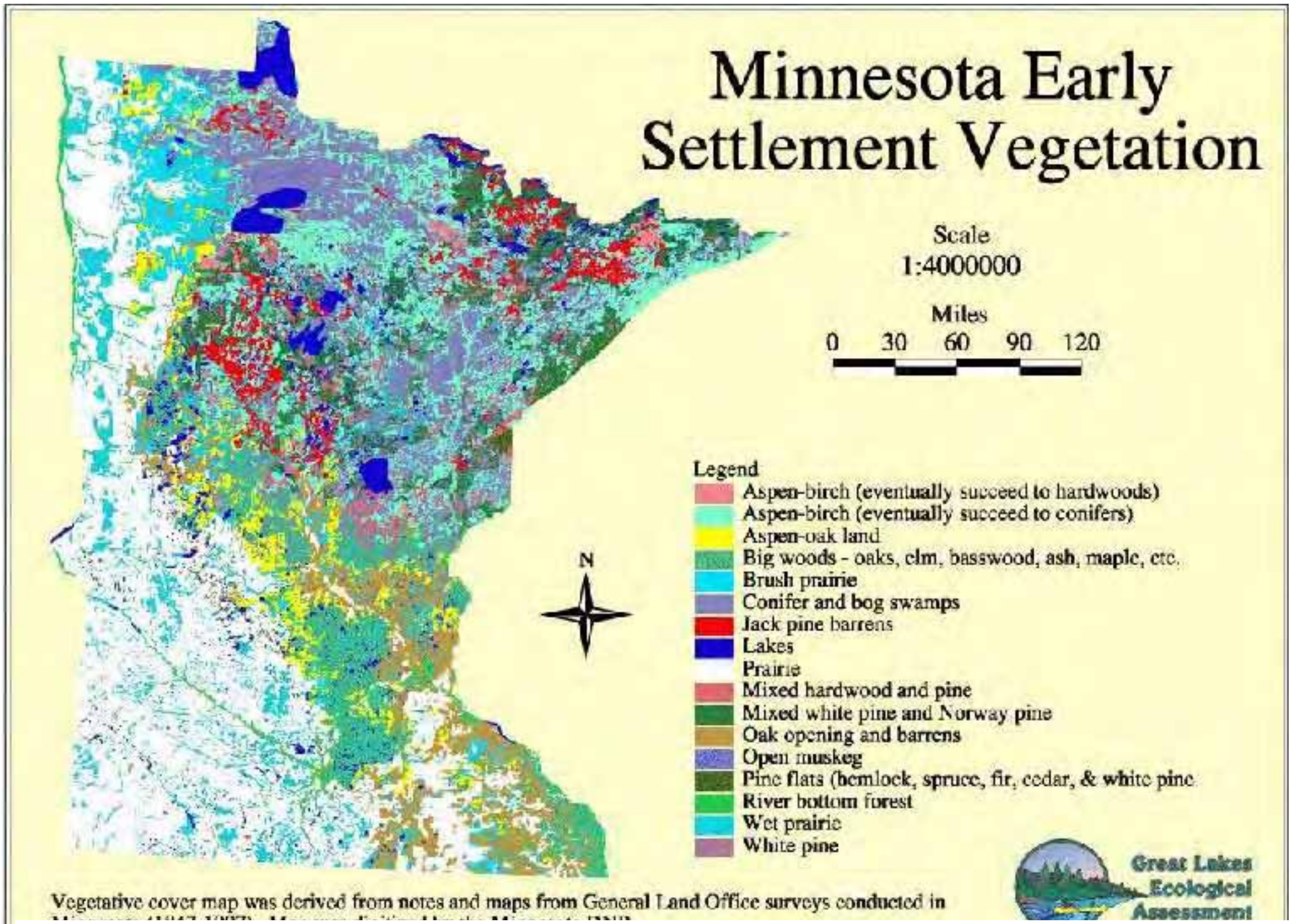
Name of System:	Marschner Map of “Pre-Settlement” Vegetation
Citation:	Marschner, F.J. 1974. The Original Vegetation of Minnesota, a map compiled in 1930 by F.J. Marschner under the direction of M.L. Heinselman of the United States Forest Service. St. Paul, MN: Cartography Laboratory of the Department of Geography, University of Minnesota. Map 1:500,000.
Figure # and name*:*	Figure 6. Historic Vegetation Map of Minnesota

Description of system:

The Minnesota early settlement vegetation map was originally created by F.J. Marschner in 1930 (Marschner 1974). Marschner's methods are not fully documented, but it is known that he used General Land Office (GLO) notes and maps from the original land survey conducted during 1847-1907 in Minnesota. Marschner is thought to have supplemented this information with descriptions of soils, landforms, and vegetation. A digitized version of the map was made available to the Great Lakes Assessment by the Minnesota Department of Natural Resources (MnDNR).

The original land survey by the General Land Office (GLO) provides the earliest systematically recorded information on forest composition in the Lake States. The GLO surveys began in 1847 and finished in 1907 in Minnesota. The GLO surveyors noted tree species and their diameters along section lines, providing a grid of transects approximately one mile apart. Locations of rivers and streams, wetlands, were noted as well as generalized maps of timber types and soil quality.

GLO records have been used for many years to provide information on tree species composition, diameter size distribution, and disturbance patches in the pre-European settlement forests. GLO data are still considered useful by the scientific community because biases are not widespread or significant enough to render the information inaccurate if interpreted at the proper spatial scale and the degree of bias can be evaluated for most applications. In most instances the vegetation has been significantly altered since the GLO surveys were completed.



Vegetative cover map was derived from notes and maps from General Land Office surveys conducted in

Figure 6. Historic Vegetation Map of Minnesota

Name of System: Ecological Land Classification Hierarchy – MnDNR

Citation: Cleland, D.T.; Avers, P.E.; McNab, W.H.; Jensen, M.E.; Bailey, R.G., King, T.; Russell, W.E. 1997. *National Hierarchical Framework of Ecological Units.* Published in, Boyce, M. S.; Haney, A., ed. 1997. Ecosystem Management Applications for Sustainable Forest and Wildlife Resources. Yale University Press, New Haven, CT. pp. 181-200.

MnDNR. *Field Guide to the Native Plant Communities of Minnesota.* Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program, MNDNR, St. Paul, MN.

The Laurentian Mixed Forest Province – 2003

The Eastern Broadleaf Forest Province – 2005

The Prairie Parkland and Tallgrass Aspen Parklands Provinces – 2005

Figure # and name: Figure 7. MnDNR Ecological Classification Sections

Description of system:

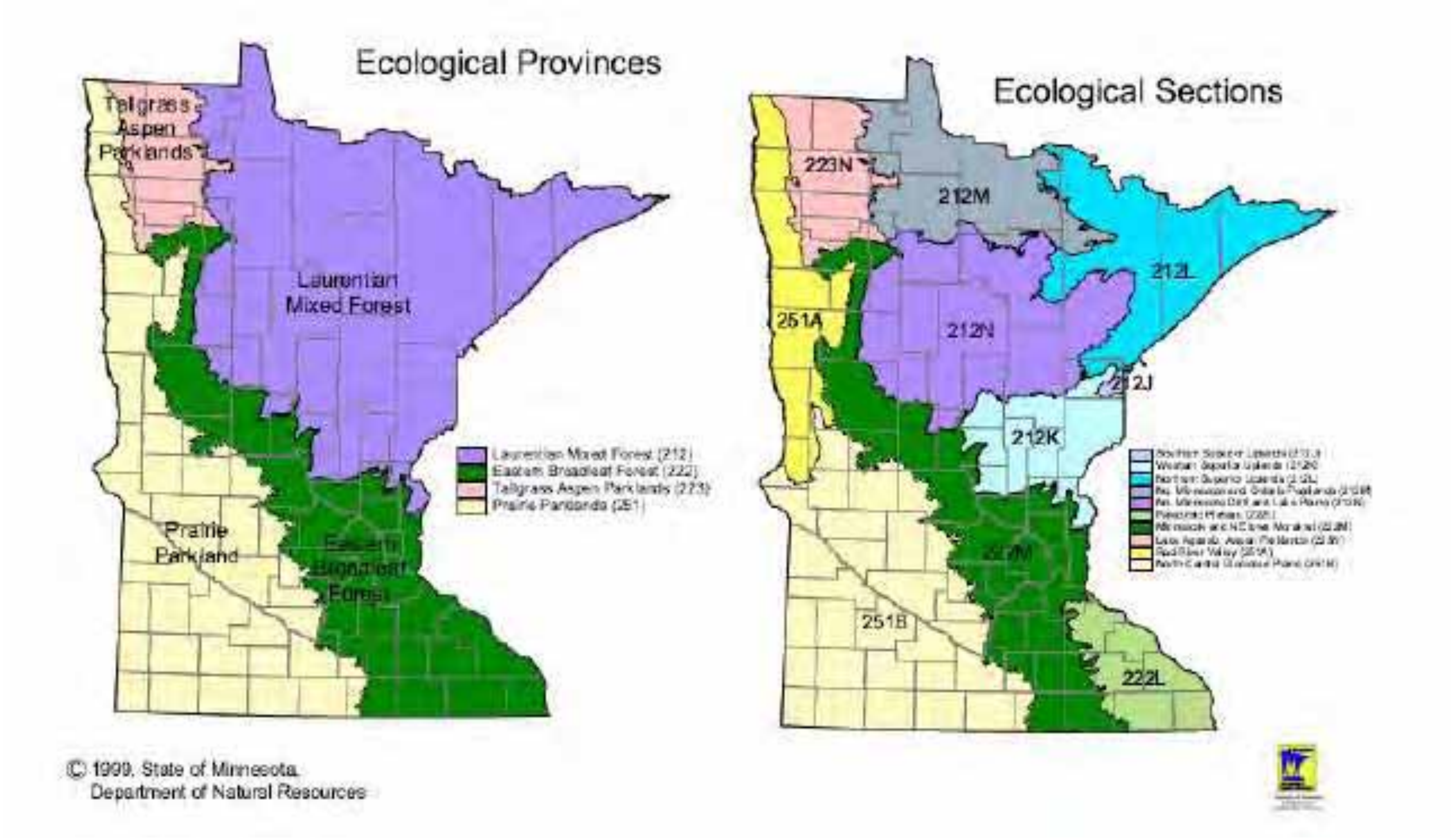
The MnDNR and the United States Forest Service have developed an Ecological Classification System (ECS) for ecological mapping and landscape classification in Minnesota following the National Hierarchical Framework of Ecological Units (ECOMAP 1993). Ecological land classifications are used to identify, describe, and map progressively smaller areas of land with increasingly uniform ecological features. The system uses associations of biotic and environmental factors, including climate, geology, topography, soils, hydrology, and vegetation. ECS mapping enables resource managers to consider ecological patterns for areas as large as North America or as small as a single timber stand and identify areas with similar management opportunities or constraints relative to that scale. There are eight levels of ECS units in the United States. Map units for six of these levels occur in Minnesota: Provinces, Sections, Subsections, Land Type Associations, Land Types, and Land Type Phases. The following describes the first three levels.

Sections are units within Provinces that are defined by origin of glacial deposits, regional elevation, distribution of plants, and regional climate. Minnesota has ten Sections. The Provinces and Sections are illustrated in Figure 7.

Subsections are units within Sections that are defined using glacial deposition processes, surface bedrock formations, local climate, topographic relief, and the distribution of plants, especially trees. Minnesota has 26 subsections.

Land Type Associations are units within Subsections that are defined using glacial landforms, bedrock types, topographic roughness, lake and stream distributions, wetland patterns, depth to ground water table, soil parent material, and pre-European settlement vegetation. Minnesota has 291 land type associations.

Native plant community classes are units of vegetation that generally have uniform soil texture, soil moisture, soil nutrients, topography, and disturbance regimes. For wooded vegetation, native plant community classes were developed by emphasizing understory vegetation more than canopy trees, under the hypothesis that in much of Minnesota understory plants are often more strongly tied to local habitat conditions (such as levels of nutrients and moisture) than are canopy trees. Native plant community types are defined by dominant canopy trees, variation in substrate, or fine-scale differences in environmental factors such as moisture or nutrients. Type distinctions were also made to describe geographic patterns within a class. Native plant community subtypes are based on finer distinctions in canopy composition, substrates, or other environmental factors. In some instances, subtypes represent apparent trends within a type for which more study and collection of data are needed. In other instances subtypes are well-documented, fine-scale units of vegetation that are useful for work such as rare plant habitat surveys.



© 1999, State of Minnesota
Department of Natural Resources

Figure 7. MnDNR Ecological Classification Sections

Name of System: Minnesota Ecoregions

Citation: Fandrei, G., S.A. Heiskary, and S. McCollor. 1988. Descriptive Characteristics of the Seven Ecoregions in Minnesota. Minnesota Pollution Control Agency.

Figure # and name: Figure 8. Minnesota Level III Ecoregions

Figure 9. Minnesota Level IV Ecoregions

Description of system:

The Minnesota Pollution Control Agency (MPCA) has been at the forefront of the use of ecoregions for water quality assessment and management work. The MPCA has developed ecoregion-based assessments of lake and stream quality, valuating water quality differences due to distinct ecoregion characteristics. The MPCA's Level III and Level IV ecoregion boundaries are similar to the EPA boundaries, but the aggregations to create the Level III ecoregions in Minnesota differ from EPA) see Figure 2).

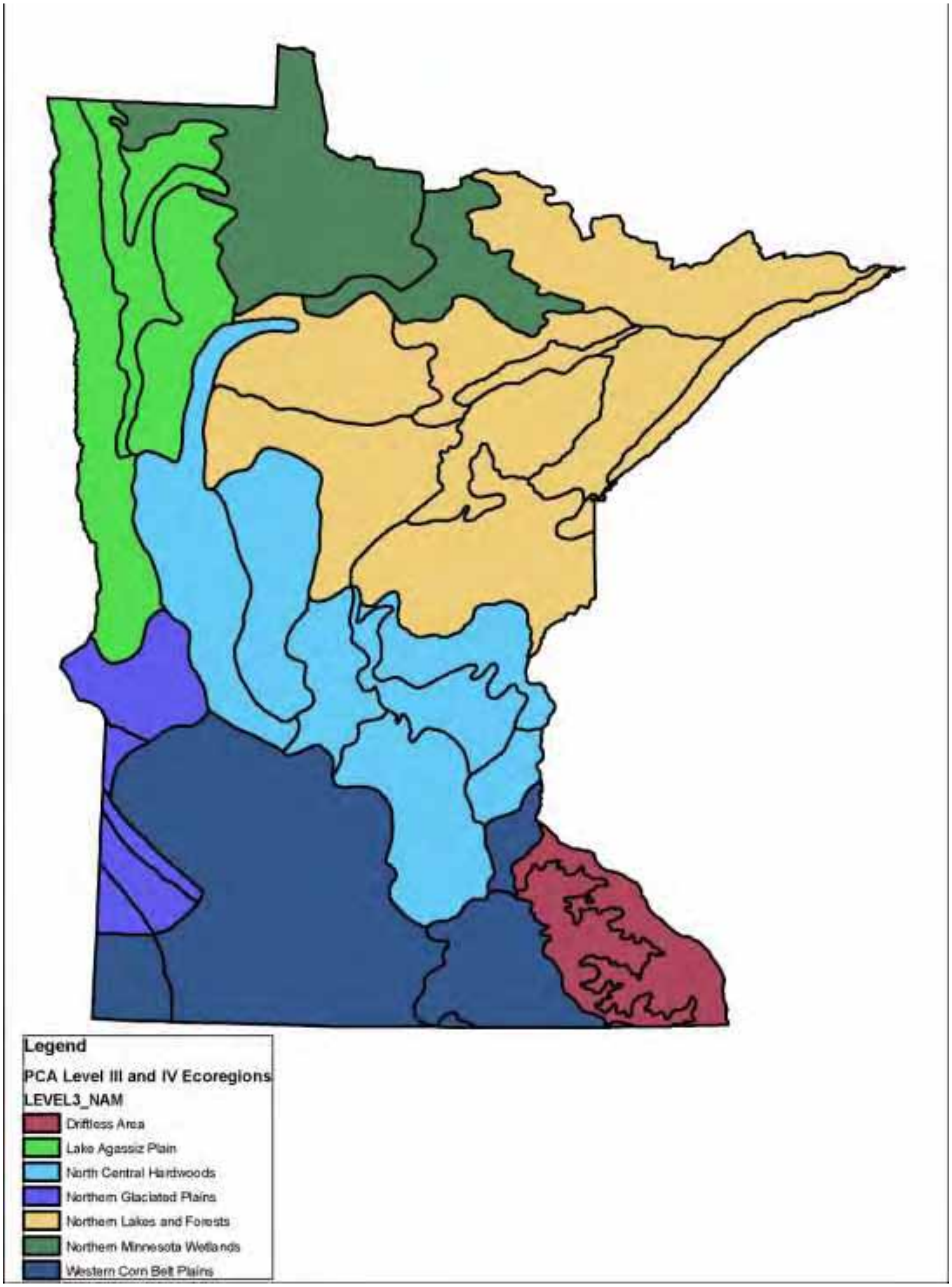


Figure 8. Minnesota Level III Ecoregions

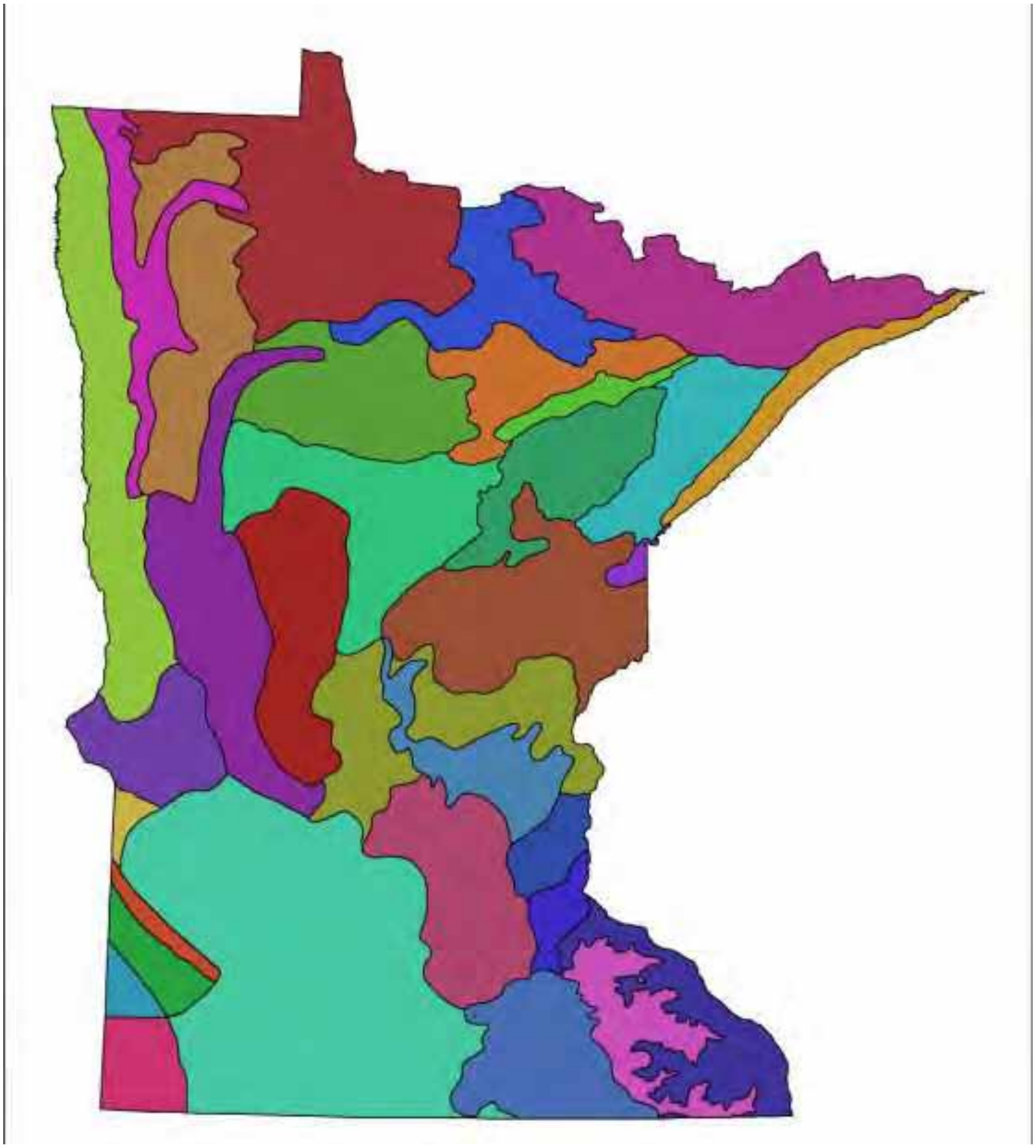


Figure 9. Minnesota Level IV Ecoregions

Name of System: Minnesota Agroecoregions

Citation: Hatch, L.K., A. Mallawatantri, D. Wheeler, A. Gleason, D. Mulla, J. Perry, K.W. Easter, R. Smith, L. Gerlach, and P. Brezonik. 2001. Land Management at the Major Watershed – Agroecoregion Intersection. Journal of Soil and Water Conservation 56(1):44-51.

Figure # and name*:* Figure 10. Minnesota Level III Agroecoregions

Description of system:

Hatch, *et al*, (2001) developed a system of agroecoregions for the Minnesota River that has since been applied across the state. The delineation of agroecoregions is based on data from the State Soil Atlas (using a 16 hectare minimum cell size) relating to classes of precipitation, soil geomorphology, slope steepness, soil internal drainage, and crop productivity.

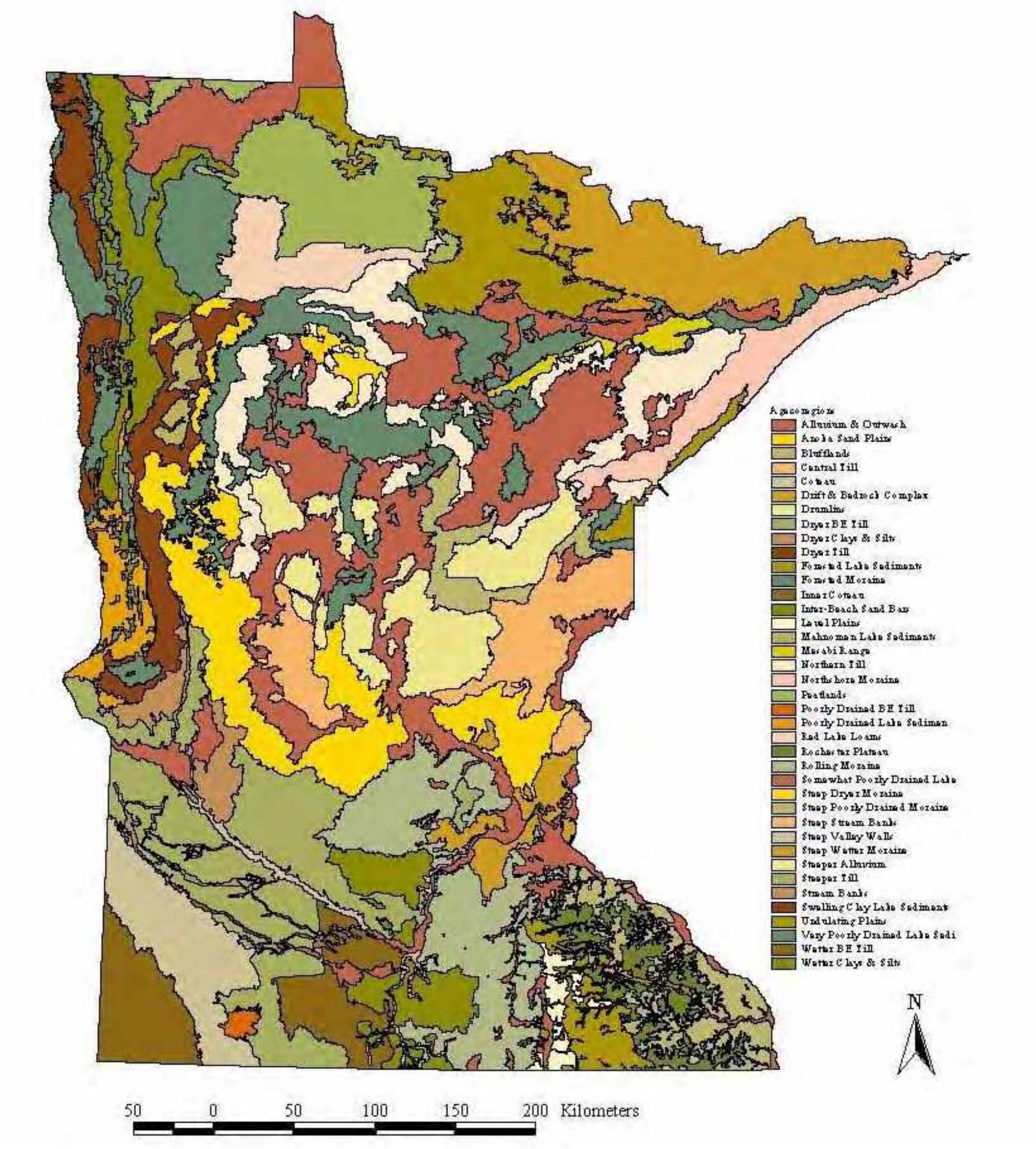


Figure 10. Minnesota Level III Agroecoregions

Name of System: Soils and Land Surfaces of Minnesota

Citation: Cummins, J.F. and D.F. Grigal. 1981. Legend to Map: Soils and Land Surfaces of Minnesota. Soils Series No. 110. Miscellaneous Publication 11. Soils Department of Soil, Water and Climate, University of Minnesota Agricultural Experiment Station.

Figure # and name: Figure 11. Soils and Land Surfaces of Minnesota.

Description of system:

The five elements that lead to the pattern of soils that that Cummins and Grigal used in compiling their map are:

1) the geologic material from which the soils originally formed (the parent material);

2) the climate in the area in which the material is found;

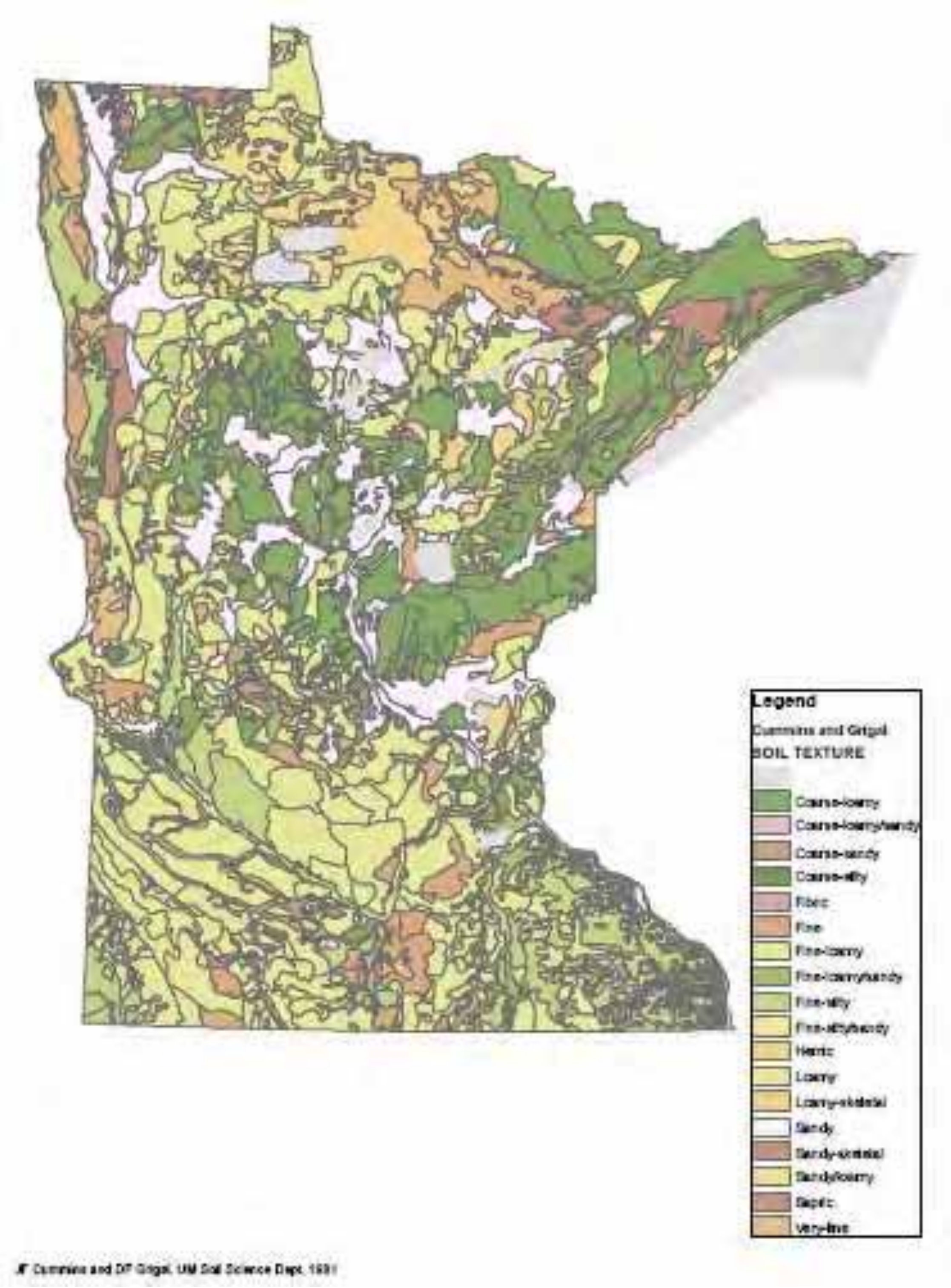
3) properties of the landscape upon which that material lay, such as its slope and aspect (relief);

4) the plants and animals that can potentially live on or in the material; and

5) the length of time during which the previous four elements have interacted.

This generalized view of the Minnesota landscape results in this data set. The polygons were delineated based on the above five characteristics and originally produced on a map commonly referred to as the Cummings/Grigal Soils Map. The map in Figure 11 delineates the major soil family textures found in Minnesota based upon Cummins and Grigal's analysis.

The map produced by Cummins and Grigal delineates the major soil areas found in Minnesota. It describes how the types of soil found in Minnesota are the result of five major environmental elements blended together, and defines each of these elements: parent material, climate, relief, living organisms, and time. It also discusses the purposes of soil classification and presents an overview of the soil orders and suborders in Minnesota.



JF Cummins and DF Grigal, UM Soil Science Dept. 1981

Figure 11. Soils and Land Surfaces of Minnesota

Name of System: Minnesota Soil Survey

Citation: U. S. Department of Agriculture. 1999. *Natural Resources Conservation Service Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys.* Second Edition. Natural Resources Conservation Service, United States Department of Agriculture Handbook Number 436.

Figure # and name: Figure 12. Status of Soil Survey Digitizing in Minnesota

Figure 13. Soils Order Map of Minnesota

Attachment 1 OSD - Southridge

Description of system*:*

Soil Survey Geographic Data Base (SSURGO) is a digital soil survey and generally is the most detailed level of soil geographic data developed by the National Cooperative Soil Survey. The information was prepared by digitizing maps, by compiling information onto a planimetric correct base and digitizing, or by revising digitized maps using remotely sensed and other information. Figure 12 shows the status of the digital soil survey completion in Minnesota.

This dataset consists of georeferenced digital map data and computerized attribute data. The map data are in a soil survey area extent format and include a detailed, field verified inventory of soils and nonsoil areas that normally occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. A special soil features layer (point and line features) is optional. This layer displays the location of features too small to delineate at the mapping scale, but they are large enough and contrasting enough to significantly influence use and management. The soil map units are linked to attributes in the National Soil Information System relational database, which gives the proportionate extent of the component soils and their properties**.**

Several aspects of the soil survey are useful for the purposes of understanding the soil characteristics and runoff potential of native soils - the Official Soil Series Descriptions and hydrologic soil groups. Both are detailed more below.

Official Soil Series Descriptions (OSD) are available for all soil series officially recognized in the United States, Territories, Commonwealths, and Island Nations served by USDA-NRCS. The Official Soil Series Descriptions (OSD) is a national collection of more than 20,000 detailed soil series descriptions, covering the United States, Territories, Commonwealths, and Island Nations served by USDA-NRCS. The descriptions, in a text format, serve as a national standard.

The soil series is the lowest category of the national soil classification system. The name of a soil series is the common reference term, used to name soil map units. Soil series are the most homogenous classes in the system of taxonomy. “Official Soil Series Descriptions” define specific soil series in the United States, Territories, Commonwealths, and Island Nations served by USDA-NRCS. They are descriptions of the taxa in the series category of the national system of soil classification. They serve mainly as specification for identifying and classifying soils. The descriptions contain soil properties that define the soil series, distinguish it from other soil series, serve as the basis for the placement of that soil series in the soil family, and provide a record of soil properties needed to prepare soil interpretations.

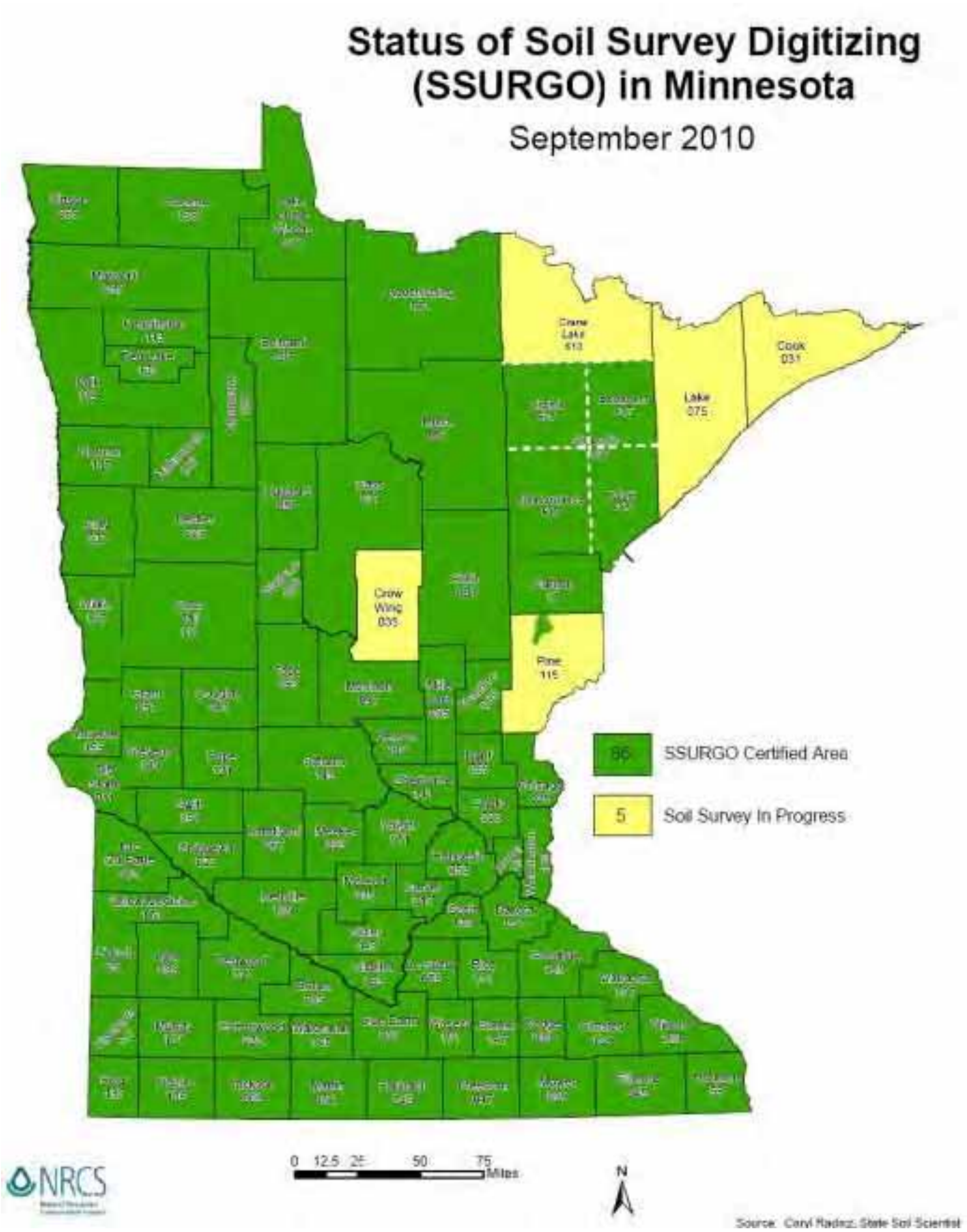
A category of soil taxonomy is a set of classes that is defined approximately at the same level of generalization or abstraction and that includes all soils. There are six categories in soil taxonomy. In order of decreasing rank and increasing number of differentiae and classes, the categories are order, suborder, great group, subgroup, family, and series.

There are 12 orders. They are differentiated by the presence or absence of diagnostic horizons or features that reflect soil forming processes. If the soils in a given taxon are thought to have had significantly different genesis, the intent has been to sort out the differences in the next lower category. Soil properties are the consequences of a variety of processes acting on parent materials over time. Distinctions among orders aid in understanding soils and remembering them on a grand scale. The processes that occur in soils must be orderly in relation to the soil-forming factors, which are climate and living organisms acting on parent materials over time, as conditioned by relief. These factors, in turn, have geographic order. The features of the soil-forming processes are clearly visible, but the details of the processes can only be inferred. The distinctions made in classifying soils cannot be based on the processes themselves because new knowledge is certain to change our ideas about the processes, but the features of the processes are facts that can be observed and measured and used as a basis for distinctions. Thus, the distinctions between orders are based on the markers left by processes that experience indicates are dominant forces in shaping the character of the soil. In this framework, the lack of features or the zero degree also is a logical criterion.

The 12 orders and the major properties that differentiate them illustrate the nature of this category. Complete definitions are given in USDA (1999) and the distribution of the orders in Minnesota is shown on Figure 13.

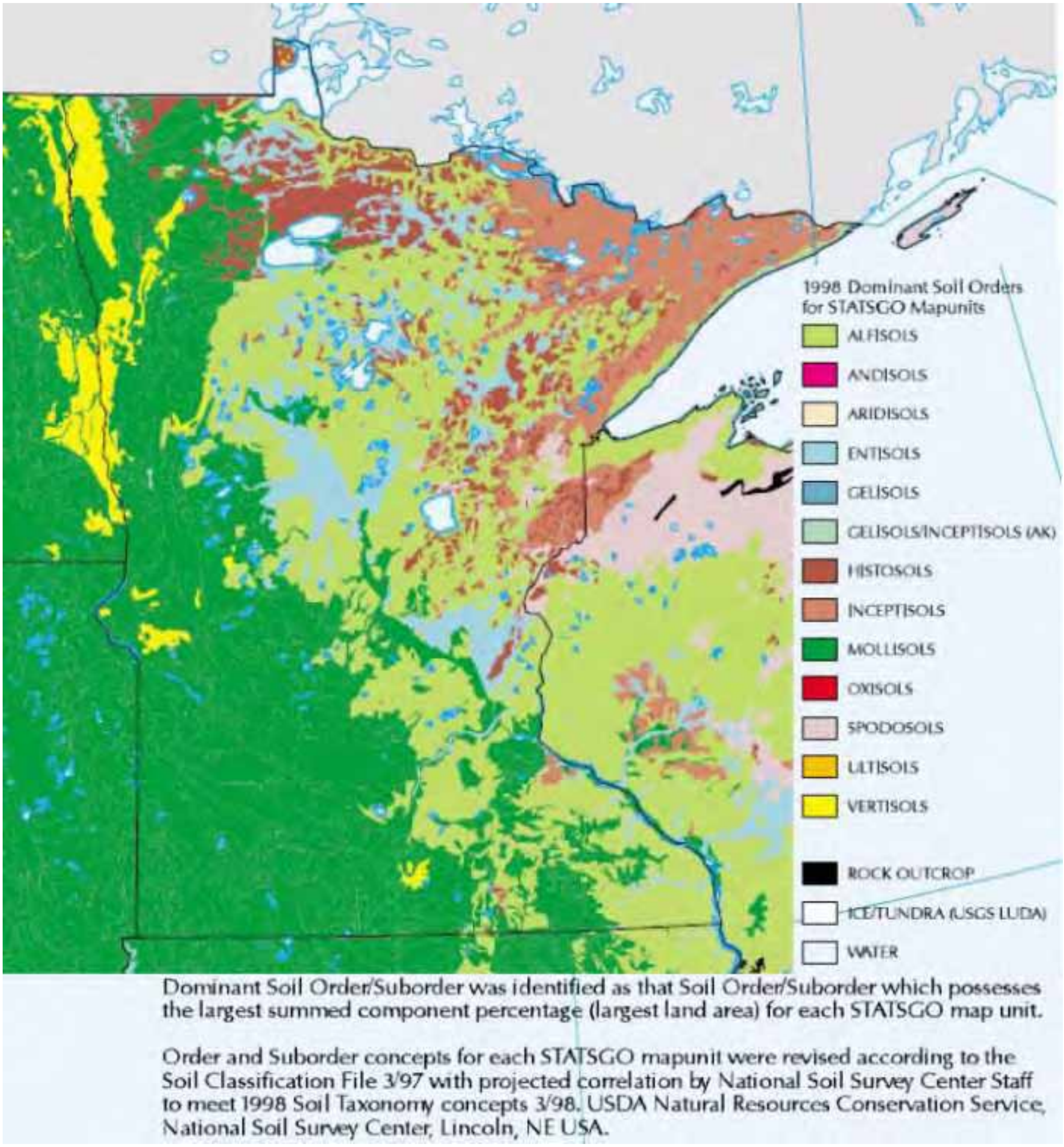
Hydrologic Soil Groups

Chapter 7 of USDA (2007) defines four hydrologic soil groups, or HSGs, that, along with land use, management practices, and hydrologic conditions, determine a soil's associated runoff curve number. See Issue Paper 4: Regional Hydrologic Metrics – Infiltration for further discussion on HSGs.



Source: Caryl Radatz, State Soil Scientist

Figure 12. Status of Soil Survey Digitizing in Minnesota

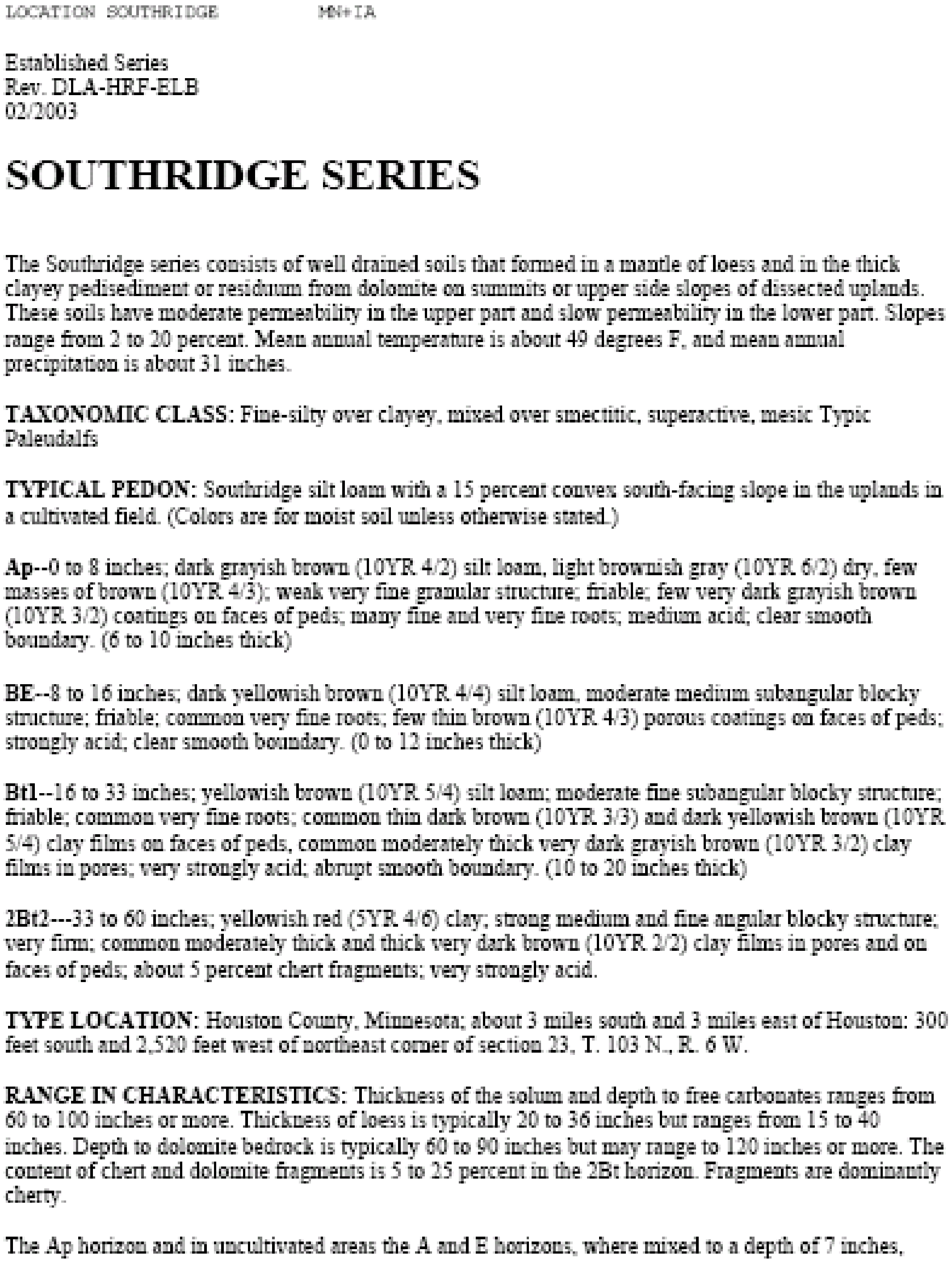


Dominant Soil Order/Suborder was identified as that Soil Order/Suborder which possesses the largest summed component percentage (largest land area) for each STATSGO map unit.

Order and Suborder concepts for each STATSGO mapunit were revised according to the Soil Classification File 3/97 with projected correlation by National Soil Survey Center Staff to meet 1998 Soil Taxonomy concepts 3/98. USDA Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE USA.

Figure 13. Soils Order Map of Minnesota

Attachment 1



LOCATION SOUTHRIDGE MN+IA

Established Series
Rev. DLA-HRF-ELB
02/2003

SOUTHRIDGE SERIES

The Southridge series consists of well drained soils that formed in a mantle of loess and in the thick clayey pedisediment or residuum from dolomite on summits or upper side slopes of dissected uplands. These soils have moderate permeability in the upper part and slow permeability in the lower part. Slopes range from 2 to 20 percent. Mean annual temperature is about 49 degrees F, and mean annual precipitation is about 31 inches.

TAXONOMIC CLASS: Fine-silty over clayey, mixed over smectitic, superactive, mesic Typic Paleudalfs

TYPICAL PEDON: Southridge silt loam with a 15 percent convex south-facing slope in the uplands in a cultivated field. (Colors are for moist soil unless otherwise stated.)

Ap--0 to 8 inches; dark grayish brown (10YR 4/2) silt loam, light brownish gray (10YR 6/2) dry, few masses of brown (10YR 4/3); weak very fine granular structure; friable; few very dark grayish brown (10YR 3/2) coatings on faces of peds; many fine and very fine roots; medium acid; clear smooth boundary. (6 to 10 inches thick)

BE--8 to 16 inches; dark yellowish brown (10YR 4/4) silt loam, moderate medium subangular blocky structure; friable; common very fine roots; few thin brown (10YR 4/3) porous coatings on faces of peds; strongly acid; clear smooth boundary. (0 to 12 inches thick)

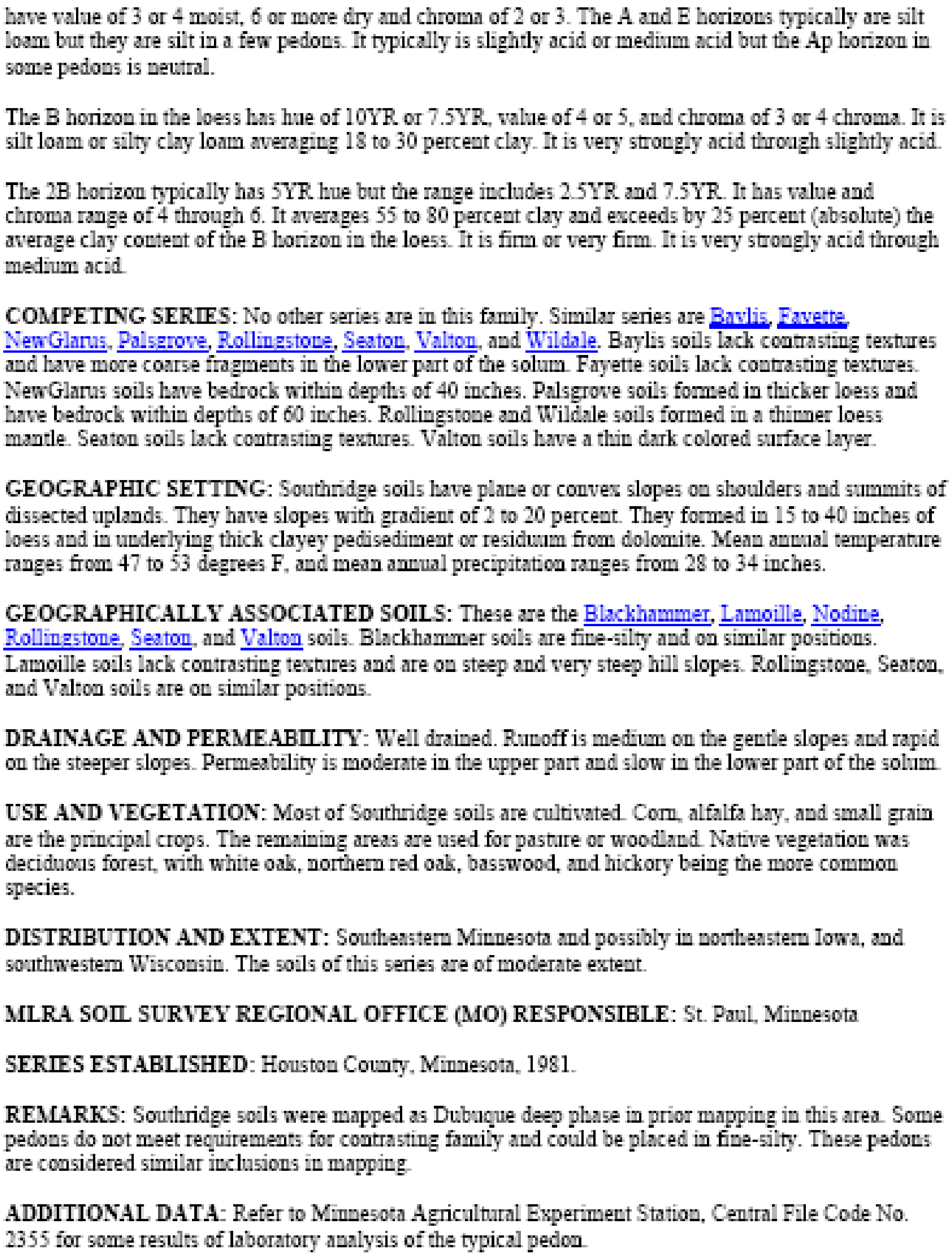
Bt1--16 to 33 inches; yellowish brown (10YR 5/4) silt loam; moderate fine subangular blocky structure; friable; common very fine roots; common thin dark brown (10YR 3/3) and dark yellowish brown (10YR 5/4) clay films on faces of peds, common moderately thick very dark grayish brown (10YR 3/2) clay films in pores; very strongly acid; abrupt smooth boundary. (10 to 20 inches thick)

2Bt2---33 to 60 inches; yellowish red (5YR 4/6) clay; strong medium and fine angular blocky structure; very firm; common moderately thick and thick very dark brown (10YR 2/2) clay films in pores and on faces of peds; about 5 percent chert fragments; very strongly acid.

TYPE LOCATION: Houston County, Minnesota; about 3 miles south and 3 miles east of Houston: 300 feet south and 2,520 feet west of northeast corner of section 23, T. 103 N., R. 6 W.

RANGE IN CHARACTERISTICS: Thickness of the solum and depth to free carbonates ranges from 60 to 100 inches or more. Thickness of loess is typically 20 to 36 inches but ranges from 15 to 40 inches. Depth to dolomite bedrock is typically 60 to 90 inches but may range to 120 inches or more. The content of chert and dolomite fragments is 5 to 25 percent in the 2Bt horizon. Fragments are dominantly cherty.

The Ap horizon and in uncultivated areas the A and E horizons, where mixed to a depth of 7 inches,



have value of 3 or 4 moist, 6 or more dry and chroma of 2 or 3. The A and E horizons typically are silt loam but they are silt in a few pedons. It typically is slightly acid or medium acid but the Ap horizon in some pedons is neutral.

The B horizon in the loess has hue of 10YR or 7.5YR, value of 4 or 5, and chroma of 3 or 4 chroma. It is silt loam or silty clay loam averaging 18 to 30 percent clay. It is very strongly acid through slightly acid.

The 2B horizon typically has 5YR hue but the range includes 2.5YR and 7.5YR. It has value and chroma range of 4 through 6. It averages 55 to 80 percent clay and exceeds by 25 percent (absolute) the average clay content of the B horizon in the loess. It is firm or very firm. It is very strongly acid through medium acid.

COMPETING SERIES: No other series are in this family. Similar series are Baylis, Fayette, NewGlarus, Palsgrove, Rollingstone, Seaton, Valton, and Wildale. Baylis soils lack contrasting textures and have more coarse fragments in the lower part of the solum. Fayette soils lack contrasting textures. NewGlarus soils have bedrock within depths of 40 inches. Palsgrove soils formed in thicker loess and have bedrock within depths of 60 inches. Rollingstone and Wildale soils formed in a thinner loess mantle. Seaton soils lack contrasting textures. Valton soils have a thin dark colored surface layer.

GEOGRAPHIC SETTING: Southridge soils have plane or convex slopes on shoulders and summits of dissected uplands. They have slopes with gradient of 2 to 20 percent. They formed in 15 to 40 inches of loess and in underlying thick clayey pedisediment or residuum from dolomite. Mean annual temperature ranges from 47 to 53 degrees F, and mean annual precipitation ranges from 28 to 34 inches.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Blackhammer, Lamoille, Nodine, Rollingstone, Seaton, and Valton soils. Blackhammer soils are fine-silty and on similar positions. Lamoille soils lack contrasting textures and are on steep and very steep hill slopes. Rollingstone, Seaton, and Valton soils are on similar positions.

DRAINAGE AND PERMEABILITY: Well drained. Runoff is medium on the gentle slopes and rapid on the steeper slopes. Permeability is moderate in the upper part and slow in the lower part of the solum.

USE AND VEGETATION: Most of Southridge soils are cultivated. Corn, alfalfa hay, and small grain are the principal crops. The remaining areas are used for pasture or woodland. Native vegetation was deciduous forest, with white oak, northern red oak, basswood, and hickory being the more common species.

DISTRIBUTION AND EXTENT: Southeastern Minnesota and possibly in northeastern Iowa, and southwestern Wisconsin. The soils of this series are of moderate extent.

MLRA SOIL SURVEY REGIONAL OFFICE (MO) RESPONSIBLE: St. Paul, Minnesota

SERIES ESTABLISHED: Houston County, Minnesota, 1981.

REMARKS: Southridge soils were mapped as Dubuque deep phase in prior mapping in this area. Some pedons do not meet requirements for contrasting family and could be placed in fine-silty. These pedons are considered similar inclusions in mapping.

ADDITIONAL DATA: Refer to Minnesota Agricultural Experiment Station, Central File Code No. 2355 for some results of laboratory analysis of the typical pedon.

Impact of Native Vegetation on Runoff

Intact ecologic and hydrologic functions in natural vegetation control the surface runoff and thus nutrient export of these natural vegetation systems. Understanding the hydrologic mechanisms involved in the nutrient export from these natural vegetation systems requires an understanding of the runoff relationships of the plants communities. Minnesota's Native Vegetation: A Key to Natural Communities (MnDNR, 1993) provide a starting point for this discussion. The vegetation classification system is based upon the native plant communities defines land cover based upon plant assemblages.

Many of these natural plant communities in Minnesota have undergone change over the last two hundred years; in some cases these changes have led to the complete loss of a community type, i.e., conversion of native prairie to agricultural production, and in other cases the conversion of one community to another, i.e., regrowth of white pineries to mixed forests following extensive logging in the late 1800s and early 1900s. Many areas of native plant coverage have been lost to the growth of urban areas; in many instances the invasion of exotic species has altered the hydrologic cycles of these urban natural areas. Wehmeyer, *et al* (21010) describe such changes in the impact of land cover changes in watersheds in Iowa. Most of these land use changes occurred shortly after initial settlement by European immigrants in Minnesota within the same historical time frames.

Within some of the major basins of Minnesota, forests and grasslands still cover up to 60% of the watershed area. The hydrologic cycling of annual precipitation in natural vegetation moves most of the water to infiltration and thus promotes stable stream base flows and reduces surface runoff. Native plant communities have relatively high rates of evapotranspiration (ET) and the loss of vegetation can lead to higher annual water yields due to decreased ET.

A detailed summary of runoff and phosphorus export can be found in the Detailed Assessment of Phosphorus States Sources to Minnesota Watersheds – Non-Agricultural Rural Runoff Technical Memorandum (MPCA, 2004). A brief summary of some of the runoff issues for native plant communities is provided in the following sections.

Forests

Singer and Rust (1975) is the most frequently cited research for runoff from deciduous forests. Based upon runoff and nutrient studies on maple-basswood forest at the Minnesota Landscape Arboretum, they found that the litter layer was responsible for high infiltration rates and thus little water loss to surface runoff occurred. Spring runoff over frozen soils accounted for most of the surface water runoff, and phosphorus loads in surface runoff occurred during the snowmelt period and immediately following leaf drop in the fall.

Sartz (1971) completed an assessment of runoff from dual-use watersheds (i.e., watersheds with agricultural and forested land covers) in the driftless area of southwestern Wisconsin near La Crosse. Sartz was able to document runoff from the upland pasture and hillside deciduous forest components of four watersheds to downhill lowland areas. The study results showed that as much as 33% of the upland flow was retained in the hillside forests and the deciduous forest hillsides generated no runoff. Sartz (1969) also reported that peak flows from undisturbed deciduous forests were 0.010 inches per hour compared to 2.42 inches per hour for alfalfa for the same 3-hour 4-inch rainfall event. Sartz, et al (1977) reported that driftless area catchments smaller than 250 hectares had no perennial streams, and cropland was the major source of surface runoff. These findings have been further confirmed by recent runoff studies in the Whitewater River watersheds (Wotzka, 2003).

Metcalfe and Buttle (1999) found that disturbances to boreal forests could lead to reduced runoff and lower stream flows due to increased evapotranspiration rates. Hewlett and Hilvey (1970) found that in mixed hardwood forests, following clear cutting, the storm flow volumes increased by 11% but this increase was confined to subsurface flow, so the site still provided very little overland flow.

Interception of rainfall occurs at multiple levels within the forest – tree canopy, tree and shrub layer stems, shrub canopy, herbaceous layer and ground litter – to reduce overland flows (Brooks, et al, 2003; Verry 1976). Other authors have reported little or no overland flow from intact deciduous or coniferous forests due to interception (Binkley, 2001; Knighton and Steigler, 1980; Metcalfe and Butle, 1999; Verry, 1969). Martin, *et al*, (2000) reported that in northern hardwood forests, clear cutting and strip-cutting lead to increased water yield due to decreased transpiration and interception. They also noted that the increased water yield disappeared within 4-6 years due to regrowth of natural vegetation. Boelter and Verry (1977) reported the phosphorus export rate from peatland forests to be 0.08 kg P/ha/yr.

Shrublands and Grasslands

While there exists a fair amount of literature on forest hydrology and nutrients, comparable literature for shrublands and grasslands is much less extensive. Many authors suggest that runoff rates and nutrient exports form these communities are low, however the supporting evidence is limited. In the case of both plant communities, the limited number of studies related to phosphorus export rates required that export rates be developed for both plant communities based upon the limited data set.

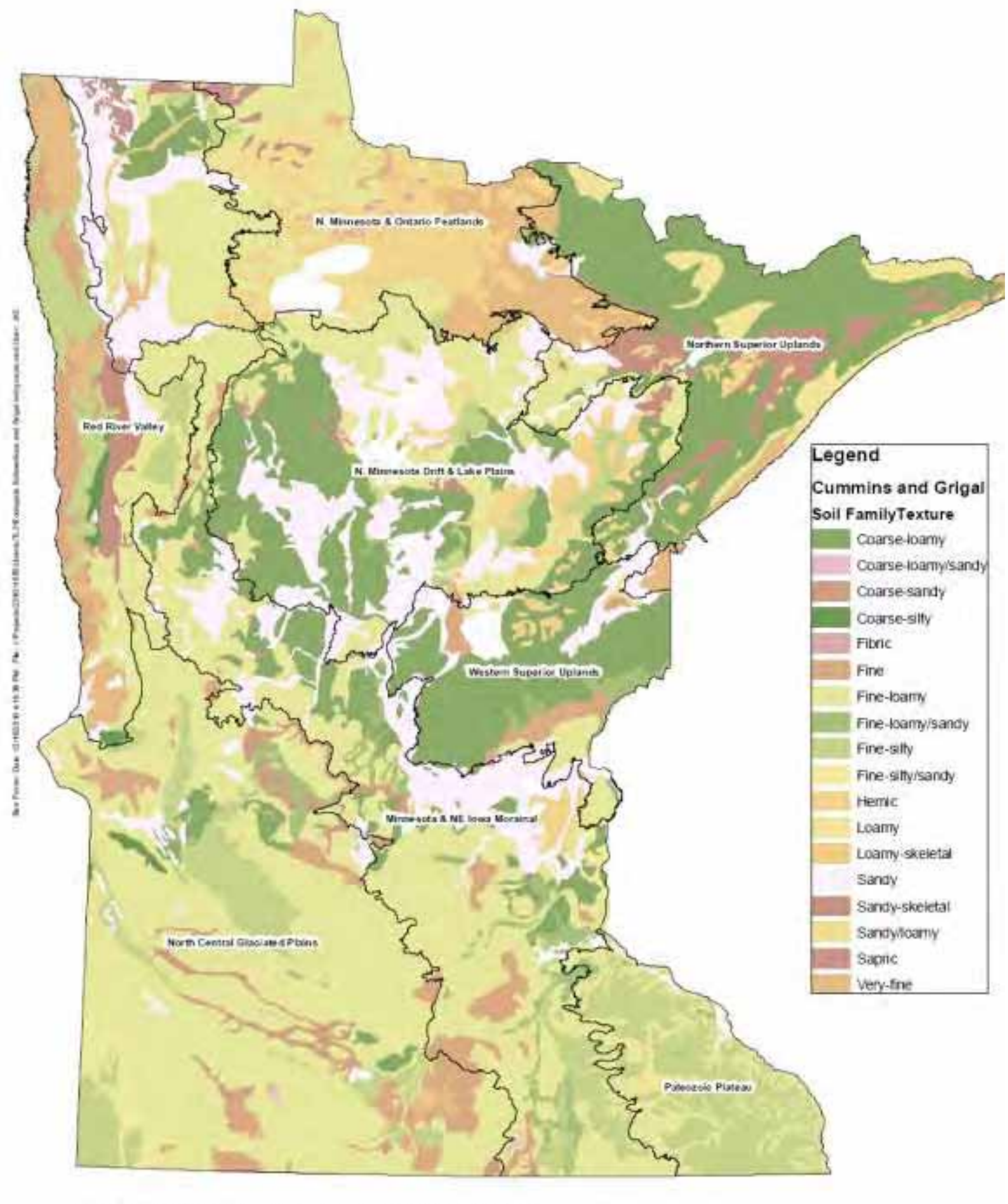
Brye, et al (2000) and Brye, et al (2002) evaluated the water and phosphorus budgets of a restored prairie near Madison, Wisconsin. The authors reported that rainfall interception by plant residue was a significant component of the annual water budget (nearly 70%). Higher soil storage and ET rates led to lower soil drainage and runoff volumes. Runoff volumes were 11% to 18% of the water budget, with a mean of 14.5% for the test plots. Snowmelt was responsible for nearly all of the runoff volumes. Shjeflo (1968) reported on water budgets for prairie pothole wetlands in eastern North Dakota, including surface runoff from adjoining upland prairies. He reported that over the 1960 to 1964 time period, snowmelt contributed 1.0” of annual runoff and rainfall contributed 0.2” of runoff (average annual precipitation was 15.84 inches) for a runoff rate of 7.5%. Winter and Carr (1980), Winter, et al, (2001) and Winter and Rosenberry (1995 and 1998) examined the water budgets for wetlands in eastern North Dakota over a 17 year period. Their results indicate surface runoff rates of 10% or less were common and most of the overland flow occurred as snowmelt or during prolonged wet seasons. In all cases, the majority of overland flow occurs in the prairie vegetation during snowmelt, which also coincides with the greatest availability of soluble phosphorus from dead and dormant above ground plant tissues.

MnDNR (1993) and Leach and Givnish (1999) suggest that many of the hydrologic and ecologic attributes of forest and prairie communities are present in shrublands. Low runoff rates, high annual evapotranspiration and limited nutrient losses of the two shrubland community components provides a basis to conclude that shrublands are intermediate with regard to phosphorus export.

Conclusions

The many classifications systems described here provide a means of describing and classifying the interactions of landscape components for many purposes. The complexity of Minnesota's landscape, whether it be due to landscape genesis, soil types, or plant community interspersion, make it difficult to identify a state-wide classification system that addresses the site specific indicators needed to develop runoff standards.

An overlay of the DNR ECS and Cummins and Grigal soil texture in Figure 14 shows that while these two systems simplify the state-wide complexity, it still may not provide the information detail needed to capture the site-based needs. The absence of, or severe alteration of, the native plant communities in most parts of the state has altered the original hydrology and makes the use of plant communities classification systems questionable. In most cases, site-based soil information may provide the most useful information for runoff characteristics.



J.F. Cummins and D.F. Grigal. University of Minnesota Soil Science Dept. 1981
MN DNR. Ecological Classification System. 1993.

Figure 14. Soils Texture and Ecological Sections

References

Albert, Dennis A. 1995. Regional landscape ecosystems of Michigan, Minnesota, and Wisconsin: a working map and classification. Gen. Tech. Rep. NC-178. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. Jamestown, ND: Northern Prairie Wildlife Research Center Online. http://www.npwrc.usgs.gov/resource/habitat/rlandscp/index.htm (Version 03JUN1998).

Bailey, R. G. 1976. Ecoregions of the United States (map). Ogden, Utah: USDA Forest Service, Intermountain Region. 1:7,500,000.

Bailey, R. G. 1983. Delineation of ecosystem regions. Environmental Management 7: 365-373.

Bailey, R. G. 1988. Ecogeographic analysis: a guide to the ecological division of land for resource management. (Misc. Publ. 1465.) Washington, DC: USDA Forest Service. 18 p.

Bailey, R. G. 1989. Explanatory supplement to ecoregions map of the continents. Environmental Conservation 16: 307-309. With separate map at 1:30,000,000.

Bailey, R.G. 1995. Description of the ecoregions of the United States. Second Edition revised and expanded (first edition 1980). Misc. publication No. 1391 (rev.). Washington, DC: U.S. Department of Agriculture, Forest Service. 108 p. Map; 1:7,500,000.Cleland, D.T.; Avers, P.E.; McNab, W.H.; Jensen, M.E.; Bailey, R.G., King, T.; Russell, W.E. 1997. *National Hierarchical Framework of Ecological Units.* Published in, Boyce, M. S.; Haney, A., ed. 1997. Ecosystem Management Applications for Sustainable Forest and Wildlife Resources. Yale University Press, New Haven, CT. pp. 181-200.

Cummins, J.F. and D.F. Grigal. 1981. Legend to Map: Soils and Land Surfaces of Minnesota. Soils Series No. 110. Miscellaneous Publication 11. Soils Department of Soil, Water and Climate, University of Minnesota Agricultural Experiment Station.

Fandrei, G., S.A. Heiskary, and S. McCollor. 1988. Descriptive Characteristics of the Seven Ecoregions in Minnesota. Minnesota Pollution Control Agency, St. Paul, MN.

Hatch, L.K., A. Mallawatantri, D. Wheeler, A. Gleason, D. Mulla, J. Perry, K.W. Easter, R. Smith, L. Gerlach, and P. Brezonik. 2001. Land Management at the Major Watershed – Agroecoregion Intersection. Journal of Soil and Water Conservation 56(1):44-51.

Küchler, A.W. (1964) *Manual to Accompany the Map, Potential Natural Vegetation of the Conterminous States United States*. Spec. Pub. No. 36. American Geographical Society, New York. 143 pp.

Küchler, A.W. (1975) *Potential Natural Vegetation of the Conterminous United States*. (2nd Ed.) (Map 1:3,168,000) American Geographical Society, New York.

Küchler, A.W. 1955. A Comprehensive Method of Mapping Vegetation. Annals of the Association of American Geographers 45(4): 404-412.

Marschner, F.J. 1974. The Original Vegetation of Minnesota, a map compiled in 1930 by F.J. Marschner under the direction of M.L. Heinselman of the U.S. Forest Service. St. Paul, MN: Cartography Laboratory of the Department of Geography, University of Minnesota. map (1:500,000).

MnDNR. 2010. Compilation of the early European settlement forest type map. Great Lakes Ecological Assessment. Accessed at: http://www.ncrs.fs.fed.us/gla/histveg/ESMap.htm

MnDNR. 2005. *Field Guide to the Native Plant Communities of Minnesota: The Eastern Broadleaf Forest Province*. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program, MnDNR, St. Paul, MN.

MnDNR. 2005. *Field Guide to the Native Plant Communities of Minnesota: The Prairie Parkland and Tallgrass Aspen Parklands Provinces.* Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program, MnDNR, St. Paul, MN.

MnDNR. 2003. *Field Guide to the Native Plant Communities of Minnesota: The Laurentian Mixed Forest Province*. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program, MnDNR, St. Paul, MN.

MnDNR. 1993. Minnesota's Native Vegetation: A Key to Natural Communities (Version 1.5). MnDNR, Natural Heritage Program. St. Paul, MN. http://files.dnr.state.mn.us/ecological_services/nhnrp/nckey.pdf

MPCA. 2004. Detailed Assessment of Phosphorus Sources to Minnesota Watersheds Prepared by Barr Engineering Company. MPCA, St. Paul, MN.

Omernik, J. M. 1977. The influence of land use on stream nutrient levels. United States Environmental Protection Agency, Ecol. Res. Series. EPA-600/3-7-104.

Omernik, J. M. 1977a. Nonpoint source-stream nutrient level relationships: a nationwide study. U.S. Environmental Protection Agency, Ecol. Res. Series. EPA-600/3-77-105.

Omernik, James M., 1987. Map Supplement: Ecoregions of the Conterminous United States, Annals of the Association of American Geographers, Vol. 77, No. 1 (March), pp. 118-125

Omernik, James M., 1995. Ecoregions: A spatial framework for environmental management. In: Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Davis, W.S. and T.P. Simon (eds.) Lewis Publishers, Boca Raton, FL. Pp. 49-62.

U.S. Department of Agriculture – Forest Service. 2010. Great Lakes Ecological Assessment. Historic Vegetation page. Accessed at: http://www.ncrs.fs.fed.us/gla/overview.htm.

U.S. Department of Agriculture USDA-NRCS Official Soil Series Description Query Facility. Soil Classification database accessed at: https://soilseries.sc.egov.usda.gov/OSD_Docs/S/SOUTHRIDGE.html

U.S. Department of Agriculture. 1984. Soil Survey of Houston County (Minnesota). Soil Conservation Service in cooperation with the Minnesota Agricultural Experiment Station. Accessed at: http://soildatamart.nrcs.usda.gov/manuscripts/MN055/0/Houston_MN.pdf.

U.S. Department of Agriculture. 1999. *Natural Resources Conservation Service Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys.* Second Edition. Natural Resources Conservation Service, United States Department of Agriculture Handbook Number 436. Accessed at: ftp://ftpfc.sc.egov.usda.gov/NSSC/Soil_Taxonomy/tax.pdf.

U.S. Department of Agriculture. 2006, Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin. Agricultural Handbook 296, USDA, NRCS. Accessed at http://soils.usda.gov/survey/geography/mlra/

U.S. Department of Agriculture. 2007. Chapter 7 Hydrologic Soil Groups Part 630 Hydrology National Engineering Handbook USDA, NRCS. Accessed at: http://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17757.wba.

U.S. Environmental Protection Agency, Western Ecology Division, Ecoregion Maps and GIS Resources, Accessed 1 May 2009. http://www.epa.gov/wed/pages/ecoregions.htm

U.S. Environmental Protection Agency. 2000a. Ambient Water Quality Criteria Recommendations Information Supporting the Development of State and Tribal Nutrient Criteria: Lakes and Reservoirs in Nutrient Ecoregion VI - Corn Belt and Northern Great Plains. United States Environmental Protection Agency, Office of Water. EPA 822-B-00-008.

U.S. Environmental Protection Agency. 2000b. Ambient Water Quality Criteria Recommendations Information Supporting the Development of State and Tribal Nutrient Criteria: Lakes and Reservoirs in Nutrient Ecoregion VII - Mostly Glaciated Dairy Region. United States Environmental Protection Agency, Office of Water. EPA 822-B-00-009.

U.S. Environmental Protection Agency. 2000c. Ambient Water Quality Criteria Recommendations Information Supporting the Development of State and Tribal Nutrient Criteria: Lakes and Reservoirs in Nutrient Ecoregion VIII - Nutrient Poor Largely Glaciated Upper Midwest and Northeast. United States Environmental Protection Agency, Office of Water. EPA 822-B-00-010.

Wehmeyer, L.L., F.H. Weirich and T.F. Cuffney. 2010. Effect of land cover change on runoff curve number estimation in Iowa, 1832-2001. *Ecohydrology*. Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10:1002/eco.162.