Ecological Regions of Minnesota:

Level III and IV maps and descriptions

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March 2020

(Image NOAA, Landsat, Copernicus; Presentation Google Earth)

A contribution to the corpus of materials created by James Omernik and colleagues on the Ecological Regions of the United States, North America, and South America

The page size for this document is 9 inches horizontal by 12 inches vertical.

Table of Contents

Appendix E: Examples of methods of regionalization

Appendix F: Minnesota Flora and Fauna Species Counts

Appendix L: Percentages of land use and land cover by Level IV ecoregions

Appendix M: Maps of Minnesota Level III and IV ecoregions and supporting data

(Most maps of supporting data have Level IV boundary lines overlaid.)

Appendix S: Descriptions of Soil Orders and Suborders

1. Introduction

Minnesota is a state with considerable variety in its landforms, climate, geology, soils, presettlement vegetation, agriculture, and human settlement patterns. This variety is reflected in part by having three of fifteen Level I ecological regions in North America, the same three regions of fifty Level II ecoregions in North America (Wiken et al. 2011), and seven of eighty-five Level III ecoregions in the conterminous US, one of which is unique to Minnesota. This document will describe the seven Level III and the thirty-two Level IV ecoregions of the state, and the process to develop the ecoregion structure.

The document has six sections and five appendices. Section 2 is an overview of the geography of Minnesota that is important for ecological patterns and processes. Section 3 compares four methods of defining ecoregions, one of which is the method mostly used in this work. Section 4 discusses the process of developing the Level IV ecoregions of Minnesota and the challenges that arose in that process. Section 5 are the descriptions for all seven Level III and all 32 Level IV ecoregions in the state. Section 6 has acknowledgments and Section 7 includes the references for the literature and the maps that contributed to this work.

Appendix E has a map on each of four pages for the four examples of different methods of regionalization discussed in Section 3. Appendix F has counts of flora and fauna species in different taxonomic categories. Appendix L has for each Level IV ecoregion, the percentages of land use and land cover classes. Appendix M has 46 maps that show the context of Minnesota in the northern Midwest of the US, the Level III and Level IV ecoregions, many of the factors that were important in defining the Level IV regions, reference information about the state, plus some of the other ecological, biological, or soil-oriented regionalizations that have been completed for Minnesota. Appendix S has brief descriptions of the classes in the soil taxonomy that are used in descriptions of ecoregions, and in Minnesota soil geography in Section 2.

2. Geographic patterns in Minnesota

Geographic location and notable features (Maps M1 – M3, M52 – M54)

Minnesota is in the Upper Midwest of the lower 48 of the United States. Before European settler colonization a number of Indigenous Nations occupied it’s area. It is now bordered by North and South Dakota in the west, Iowa in the south, Wisconsin and Lake Superior in the east, and the Canadian Provinces of Quebec and Manitoba in the north. Minnesota has the northernmost point in the lower 48 states, at about 49º 25' north latitude in the exclave called the Northwest Angle. The Northwest Angle is separated from the land of Minnesota by the Lake of the Woods, and has a land border with Manitoba. The part of the state bordering Lake Superior and extending north from Duluth to the Canadian border in the northeastern part of the state is called the Arrowhead Region from its shape on a map of the state. The southeast area adjacent to the Mississippi River is part of the multi-state area known as the Driftless Area that extends into Wisconsin, Iowa, and Illinois (see the description of the ecological region for this area). The western border of the state from the Canadian border south to Breckenridge is formed by the Red River of the North that flows north, ultimately to Hudson Bay. The border from the southern end of the Red River continues south by the Bois de Sioux River, Mud Lake and Lake Traverse all of which drain north to the Red River. The eastern border from Pine County south to the Iowa border is formed by the St. Croix River until its confluence with the Mississippi River, and from there south by the Mississippi. Minnesota has a hydrological triple point just north of the Mesabi Range from where streams and rivers flow north to Hudson Bay, east to the Gulf of St. Lawrence, and south to the Gulf of Mexico. The Twin Cities of Minneapolis and St. Paul were the 16th largest metropolitan area in the US, with a population of approximately 3,600,000 in 2017 (https://factfinder.census.gov).

Climate (Maps M4 – M10)

Minnesota has a mid-latitude humid continental climate with warm to hot summers and cold winters. The Köppen-Geiger climates for Minnesota based on data from 1980 to 2016 are Dfa: cold, no dry season, hot summer, in the southern part of the state, and Dfb: cold, no dry season, warm summer, in the northern part.

There is a small outlier patch about 30 km west of Detroit Lakes of Dwb: cold, dry winter, warm summer (Beck et al. 2018). Mean annual precipitation in Minnesota has a strong gradient from higher values in the southeast to values slightly more than half of those in the northwest. The range is from more than 900 mm (36 inches) per year to less than 525 mm (21 inches) (all climate data are means for the period 1981 – 2010). Both mean and minimum temperatures for the month of January have a strong gradient from south to north, warmer to colder, with a small area of warmest temperatures in the southeast corner of the state, close to the Mississippi River. Minimum January temperatures range from -22º C (-8º F) to -13º C (+8º F). The pattern for mean and maximum temperatures for July have more spatial variation with a mild gradient from southwest to northeast, warmer to cooler. The warm maximum July temperatures have a range from 21º C (70º F) to 28º C (83º F), and extend into the Red River Valley. Some of the warmest are near the western part of the Minnesota River and near the Twin Cities. Growing degree days (in Fahrenheit) have a southwest to northeast pattern, similar to July temperatures. The highest values (more than 2700), over twice the lowest (less than 1300) in the tip of the Arrowhead Region and in the Mesabi Range, are near the Twin Cities and in the southern part of the Des Moines lobe in Nicollet, Brown, Blue Earth, Watowan, Martin, and Faribault Counties.

The future climate of Minnesota appears likely to change considerably. Both the long-term and recent rates of warming in Minnesota are faster than national and global trends (Minnesota Interagency Climate Adaptation Team 2017). From 1895 to 2015 the average annual temperature in Minnesota has increased by 1.1º C (1.6º F). Winter temperatures have increased by about twice the annual rate. The Upper Midwest has the highest rates of increase in the conterminous US and, in Minnesota as in other states, the northern part of the state has higher rates of increase than the southern part does. Much larger rates of increase in temperature are projected by the end of the 21st Century. Precipitation has also increased on average across the state and the number of extreme events in temperature and precipitation has increased as well. The Köppen-Geiger climates predicted for Minnesota for the period 2071 – 2100 are Dfa for almost all of the state with a very small Dfb section at the northeast tip of the Arrowhead Region adjacent to Ontario and Lake Superior (Beck et al. 2018). Continued changes in climate through the 21st Century are likely.

Elevation, physiography, and topographic form (Maps M11 – M13)

The highest point in Minnesota, Eagle Mountain at about 700 m, is only about 24 km from the shore of Lake Superior which is the lowest point at about 170 m. Three areas of higher elevations, in the northeast inland from the Lake Superior shore, in the northwest and surrounding southern Clearwater County, and in southwest Minnesota, contrast with lower elevations in the valleys of the Red, Minnesota, and Mississippi Rivers. Topographic form is very flat in the Red River Valley, in parts of the wetlands of the northern part of the state, and in other areas of former glacial lakes. Steep bedrock areas are along the border with Ontario, and the cliffs along Lake Superior. Other steep areas are often associated with terminal moraines whereas rolling terrain forms much of the Des Moines Lobe (see description of that ecoregion), and the northeastern lakes and highlands area. The physiography of Wright (1972b) provides a regional geography of surficial geology.

Geology (Maps M14- M21)

Bedrock geology of Minnesota is characterized by Precambrian rocks of the Laurentian Upland in the north-central and northeast, and Paleozoic rocks in a narrow strip along the northwest and in most of the south. The bedrock is almost completely overlain, however, with more recent soils and rocks supplied by Pleistocene glaciation. There are only outcroppings of older rocks in the Arrowhood Region, in the southwest corner of the state near Pipestone, and in a few places along the Minnesota River Valley and in a few other areas. The Glacial Lake Agassiz lake bed covers an area in the northwestern part of the state north and west of and bounded by a concave arc from Traverse County to northern St Louis County. Included are Upper and Lower Red Lake. There is a smaller glacial lake bed in southern St Louis and Itasca Counties stretching into northern Aitken County, and additional lake beds mostly in Blue Earth County, in southern Pine and Kanabec Counties, and in Carlton County. A major glacial moraine that informs contemporary topography is the Alexendria Moraine in an arc paralleling the Glacial Lake Agassiz lake bed in the northwest, and continuing southeast toward the Twin Cities, and then south as the Owatonna Moraine to the Iowa border. Other moraines in the northern part of the state and two parallel moraines in the southwest are notable in current topography. Much of the glacial topography comes from a succession of lobes during the latest stage of Pleistocene glaciation, the Wisconsin stage. The more recent lobes, particularly the most recent Des Moines Lobe, often cover features from earlier lobes. Other features resulting from glaciation include lakes from melting ice in situ, outwash from melting ice drainage, terraces, shorelines of Glacial Lake Agassiz, and extensive peat deposits in the eastern parts of the Glacial Lake Agassiz lake bed. The complex history and landscape forming processes of the Pleistocene glaciation are described in great detail in Wright (1972a).

Soils (Maps M22 - M28)

Minnesota has seven of the eleven major types of soils, called soil orders. Prairie soils with dark color and high nutrient content (Mollisols) cover much of southern and western parts of the state. Fertile forest soils with light gray or brown color and being generally moist (Alfisols) cover much of the central and southeastern parts. Relatively recently formed soils in river bottoms and sandy plains (Entisols) are found also in the central part of the state in scattered areas. Soils formed recently from plant material in wet environments (Histosols), creating marshes and bogs, cover areas in the eastern part of the Glacial Lake Agassiz lake bed, and smaller areas in other parts of the state. Soils with retarded soil formation (Inceptisols) cover significant areas in northeastern parts of the state. Soils with a high clay content and forming cracks in the surface (Vertisols) are only found in the lake deposits of former Glacial Lake Agassiz. There is a division in Minnesota between soils classified as having a mesic temperature regime, in the southern part of the state, and soils having a frigid temperature regime, in the northern part of the state. The challenges for agriculture in frigid soils are reflected in the kinds of crops, if any, that are grown in the north compared with the south. Soils with high organic matter, iron, and aluminum from leaching in humid areas are found in small areas in the east-central part of the state. Soil capability is high for much of the state, with class one and two soils covering about two-thirds of the state except for areas of Inceptisols, Histosols, and sandy soils. The soils nomenclature is defined in Appendix S.

Presettlement vegetation (Maps M29 - M31)

The vegetation at the time of the Public Land Surveys, which happened between 1847 and 1907, generally preceded extensive permanent settlement by European Americans. One of three or four major patterns of this vegetation was prairie and prairie wetland in the bed of Glacial Lake Agassiz, continuing south and east to the Iowa border. The eastern edge of prairie was about one county wide from the Canadian border south, and then from Grant County south it angled east roughly along the eastern borders of Grant, Pope, Kandiyohi, Sibley, Nicollet, Blue Earth, and Faribault counties. Another strip of contiguous prairie, less than a county wide, started in Dakota County south of the Twin Cities and continued south to Mower County. A second pattern, less contiguous than that of prairie, was hardwood forests that also covered an area from the Canadian to the Iowa border. This pattern was 15 to 95 km wide in a northwest to southeast direction and included aspen parkland in the north, significant areas of oak woodland and brushland, and significant areas of maple-basswood forest. The maple-basswood forests generally occupied areas of Alfisols with the oak forests interleaving where other soil orders were present. The third pattern of conifer forests covered northeastern Minnesota from parts of Pine and Kanabec counties north, and bordered on the west by the hardwood forests, and prairie wetlands and aspen parkland in the northernmost areas. A fourth pattern were the peatlands in the eastern section of Glacial Lake Agassiz. Along many rivers, including the Red, Minnesota, and Mississippi, were floodplain forests of water tolerant species. In all areas fire was an important force in rearranging the patterns of vegetation communities, whether ignited by lightning or by humans, as Heinselman (1996) has shown in great detail for the Boundary Waters Canoe Area Wilderness.

Less than 1% of the original prairie remains in Minnesota and is only present in very small pieces. Less than 20% of the hardwood forests remain and almost none in what was the Big Woods (see that ecoregion). The remnants of hardwood forest are smaller and more isolated (Tester 1995). Most of the loss for both prairie and hardwood forests has been to agriculture and, to a lesser extent, to urban land use. Most of the area with conifer forest has remained in forest but the species composition has changed, after logging, from older growth white and red pines to aspen-birch (Tester 1995). Only near the Canadian border in Koochiching and in the

Arrowhead counties has the presettlement forest survived in a more wild condition. Much of the peatland remains, after many failed attempts at ditching in the early 20th Century.

Current land use and land cover (Maps M32 - M33)

Contemporary land use and land cover follows patterns in soils and presettlement vegetation with intensive agriculture in the prairie soils from northwest to south central parts of the state, forests in the northeast, less intensive agriculture in the center of the state between the prairie soils and the northeast forests, and wetlands in the eastern part of Glacial Lake Agassiz. Mining occurs in several strips of mountain ridges in the northeast, and the Twin Cities is a large metropolitan area at the confluence of the Minnesota and Mississippi Rivers. Indian reservations cover about 1.9 % of the state by treaties and land sales now in effect. The distribution of land use and land cover classes by Level IV ecoregions is included in Appendix L.

Lakes, rivers, and watersheds; water quality (Maps M34 – M40)

Minnesota is rich in water resources. There are over 12,000 lakes of about 4 hectares in size or greater (Heiskary and Wilson 1989). The headwaters of the Mississippi River are in North Central Minnesota and it flows almost 3800 km until it leaves the state flowing south between Wisconsin and Iowa (https://www.dnr.state.mn.us/watertrails/mississippiriver/index.html). Geographic patterns of water quality for alkalinity (potential resistance to acid rain) and phosphorus loading (potential stimulus for eutrophication) are generally similar. In the very northeastern part of the state, in the Arrowhead Region along the Canadian border, the alkalinity is lowest, meaning lakes there are more likely to be susceptible to acid rain effects, and the phosphorus loadings are also lowest, meaning they are more likely to be less susceptible to eutrophication. There are several small areas of medium alkalinity in Itasca, Pine, and Kanabec Counties; the remainder of Minnesota has high alkalinity. Phosphorus loadings increase to the west and to the south of the Arrowhead Region. The highest values are in the four Level III ecoregions that intersect the western and southern borders of the state, plus the Northern Minnesota Wetlands and several agricultural areas in the North Central Hardwood Forests (Omernik and Griffith 1986, Omernik et al. 1988). Recent assessments of phosphorus loadings have been published by the Minnesota Pollution Control Agency and the Minnesota Department of Natural Resources (2019).

Research teams at the US Environmental Protection Agency have recently published analyses of the biotic condition and watershed integrity of rivers, streams, and watersheds in Minnesota (Hill et al. 2017, Thornbrugh et al. 2018). Biotic condition is based on national probability surveys of river and stream condition using a multimetric index of benthic invertebrate assemblages. Watershed integrity is based on national scale mapping for watersheds of variables that are hypothesized to influence watershed integrity. An index of watershed integrity was defined as the product of separate indices of hydrological, water chemistry, sediment, hydrologic connectivity, temperature, and habitat provision variables. A related index of catchment integrity was defined and calculated for local drainages (not upstream drainage and thus not usually complete watersheds) for rivers and streams. Geographic patterns in biotic condition, and in watershed and catchment integrity, echo many of the other patterns in Minnesota. Predicted biotic condition is not a complete coverage of Minnesota as they were calculated only for rivers and streams that have the same characteristics as river and stream reaches that were sampled; the indices of watershed and catchment integrity were calculated for the entire state. Nevertheless the patterns in all three water-based indicators are similar with higher quality condition and integrity in the northeast declining to the west and south. The intensive agricultural parts of the state have the lowest quality condition and integrity.

Flora and fauna (Maps 41 - 44)

Because of the strong gradient in Minnesota from the cold, shallow soils above the Canadian Shield, and relatively intact forests of northeastern-most part of the state to the warm, deep prairie-built soils of the agricultural parts of the state to the west and especially to the south, Minnesota has a wealth of diversity in flora and fauna. For example, three iconic mammals, Canada lynx, gray wolf, and moose, are more likely to be seen here than in most other states along the Canadian border from New York to northwestern Montana. The numbers of species in the most common taxa of flora and fauna are documented in Appendix F.

The state, through the Department of Natural Resources (DNR), has devoted considerable effort to developing conservation plans for threatened and endangered species, and species determined to be of special concern (all these species also listed in Appendix F). A biodiversity significance rank based on the status of rare species, native plant communities, and landscape characteristics gives guidance to biologists in determining where to focus conservation (Maps M42, M43, M44). Places with important biology resources in the state are also ranked for study and conservation action in the state Wildlife Action Plan for 2015-2025 (MN DNR 2016). These maps suggest that the most important areas for preserving flora and fauna in Minnesota are in Level III ecoregions 49 and 50 (especially Level IV ecoregion 50n), and additionally, Level IV ecoregions 48b, 48d, 51b, and 52b, as well as corridors on the west side of the state for grassland restoration. In addition to the Wildlife Action Plan, DNR also has an active land protection plan for “scientific and natural areas.” This program protects generally small “areas of greatest biodiversity significance, native plant communities, habitat for rare species, and significant unique natural features such as geological formations” (MN DNR 2014).

3. Methods of geographic regionalization

Curious and observant travelers have been describing different regions of the world at least as long ago as Herodotus did some 2500 years ago. Islamic travelers from 600 to 1000 years ago and then European travelers in the late medieval period into the Renaissance described their experiences in different regions. With the opening up of travel by Europeans by sea to the Americas and Asia different parts of the world became better known (James and Martin 1981, Cresswell 2013).

In the 20th and 21st Centuries geographers and others have developed many approaches to studying regions of many different kinds. For defining and developing maps and descriptions of regions that represent the ecology of large areas, four different methods illustrate a variety of ways to proceed.

The first method can be characterized as a deductive composition of ecological regions across space as successive divisions based on hierarchical relationships of biophysical causes. An example of this approach is Robert Bailey’s work (Bailey 2009). Bailey argues that the initial, macroscale divisions are determined by climate modified by topography and as indicated by natural vegetation. At the mesoscale, landforms created by geology create subregions within the macroscale regions. At the microscale, soils and local climates create further divisions with the mesoscale regions. In the map of Ecoregions and Subregions of the United States, created by Bailey and colleagues (1994, 1995), they delineated macro and mesoscale regions which at the highest level have three major “domains,” humid, humid-tropical, and dry. At the next level there are eleven “divisions” with eight “mountain divisions” associated with eight of the non-mountain divisions. At the next level there are 35 “provinces” within the two types of divisions. The finest scale delineated by the authors on the 1994 map are mesoscale “sections” that vary in number from one to thirteen within their respective provinces. See map E1.

The next method is also based on a deductive hierarchical division of space but in the context of a GIS process of successive layers of data, creating one scale of ecological regions. Roger Sayre and colleagues (2009) have created a product of this type they call “ecosystems.” The first step is overlaying 12 biogeographic regions with 127 classes of isobioclimates to create 435 classes of “Mesoscale Bioclimate/Biogeographic Regions.” The second step combined 17 classes of surficial materials lithology, 10 classes of land surface form, and four classes of topographic moisture potential into 813 classes of “Local Abiotic Environments.” The final steps overlayed the bioclimate regions with the abiotic environments to create, initially, 13,482 “Ecosystem Footprints,” which were then aggregated to 419 “NatureServe Ecosystems” for the conterminous US. See map E2.

A different approach is an empirical discovery of ecological regions as observable clusters of similarities in patterns of biophysical variables across space. William Hargrove and Forrest Hoffman (2005) used this approach to delineate pre-defined numbers of ecoregions using a clustering algorithm whose one parameter is the number of clusters. To prepare data for clustering they selected GIS datasets that represented phenomena that they wanted to inform the result. In one study they used nine variables: plant-available soil water capacity, soil organic matter, soil nitrogen, depth to seasonally high water table, mean precipitation during the growing season, mean solar insolation during the growing season, degree-day heat sum during the growing season, degree-day cold sum during the non-growing season, and elevation. They have also used 17 variables and 37 variables in other studies (Baker et al. 2010, Hoffman et al. 2012). See map E3.

The fourth method is also an empirical discovery method. Rather than a statistical approach, however, this method identifies ecological regions as unique patterns of spatial correlations of biophysical phenomena varying in importance from place to place. This method relies on the convergence of evidence from mapped data and literature, and the investigators' judgment on the relative importance of the many factors that are relevant in different parts of the study area. James Omernik (1987) first published his approach using this method for a set of 87 ecological regions for the conterminous US. These regions became Level III of the Omernik system (Omernik and Griffith 2014). Subsequent work included collaboration with Canadian and Mexican colleagues for larger area ecoregions at levels I, II, and III (Commission for Environmental Cooperation 1997, Wiken et al. 2011), and the eventual delineation of finer area Level IV regions for all of the conterminous states. See map E4.

The map appendix includes maps (M45 - M50) of regions of Minnesota by other groups that have relevance to this work. These groups include the US Forest Service, USDA Natural Resources Conservation Service, and Minnesota Department of Natural Resources.

There are many forces creating variation in space, forces in the atmosphere, in the deep earth, in the soil, from plants, from non-human animals, and especially in the current period, from humans. This variation exists at all scales. The merit of the method of Omernik is to recognize that what is most prominent in creating the variation in one area may not be true in a nearby area, even though there is significant autocorrelation in space for individual forcing functions. Most other methods assume, implicitly or explicitly, that forces have a hierarchical or static importance across space. The Omernik approach has been successful in helping potential users of ecoregion maps in various types of environmental management and reporting, research design, and public communication of significant geographical variation at the state scale. For the work in Minnesota the Omernik system represented the most useful method.

4. Development of Level III and IV ecological regions for Minnesota

The work on the initial version of ecological regions for the conterminous US, subsequently becoming Level III, was conducted in the mid-1980s by Omernik and published in 1987. This work was "based on the hypothesis that ecosystems and their component display regional patterns that are reflected in spatially variable combinations of causal factors. These causal factors include climate, mineral availability (soils and geology), vegetation, and physiography. Although these factors interact, the importance of each factor in determining the character of ecosystems varies from place to place." Omernik argued that "by analyzing a combination of small scale maps of the important causal factors and of integrative factors (such as land use), distinct regional patterns of ecosystems can be perceived" (quotations in this paragraph from Omernik 1987). These level III ecoregions have been used for assessment and management of rivers and lakes in Minnesota (Heiskary and various others 1987, 1988, 1989, 2008, 2019; Ramstack and others 2004; Anderson and others 2016).

The work on Level IV described here was conducted under the aegis of the Omernik system and started with the Omernik Level III ecoregions as a basis. The method of discovery is described in some detail in Omernik and Griffith's 2014 paper. The process in Minnesota included in the early stages two visits to Minnesota to talk with potential users of more detailed ecoregions. Many maps of relevant phenomena were assembled from some materials already available at the US EPA research laboratory in Corvallis, and from sources online. Some of the maps that have been used are represented in Appendix M. Also considerable literature was assembled on soils, vegetation, wildlife, geology, and geography. The references list most of these documents.

With these many materials to assist, patterns among them were studied and compared until the accumulated knowledge suggested the appropriate division of the Level III regions into subregions, with possible minor changes to the boundaries of Level III also. This process, as with any regionalization process, cannot be considered a final reckoning of the ecoregionality of Minnesota because not only will further knowledge affect possible changes, but the forces of change interact in complex ways and change themselves in spatial distribution and importance.

There were a number of challenges for the work in Minnesota. A major missing ingredient was a field trip around the state with scientists and scholars with expertise in the major influencing factors in Minnesota's landscapes. This activity was conducted in at least 30 other states (Omernik and Griffith 2014) and has proved to be a valuable exercise in cross-discipline discussion of the importance of various factors in different parts of a state, and therefore in helping to improve a map of ecoregions at a more detailed scale.

Because Level IV ecoregions for Minnesota were initiated after those for all surrounding states were completed, the process in Minnesota needed to extend existing lines crossing the borders of these other states: North and South Dakota, Iowa, and Wisconsin. In some cases this was easier than in others. The complex of determining factors changed in several cases for a small portion in Minnesota of the ecoregion from the adjacent state. In one case an ecoregion was subdivided in Minnesota causing the adjacent state to implement that division also.

Minnesota's landscape, particularly in the north-central part of the state, is a complicated mixture of remnants from different lobe advances, retreats, moraines, former lakes, existing lakes, valley tunnels, and outwash features from the Wisconsin stage of Pleistocene glaciation. In some cases the variation in factors suggested a level of ecoregion delineation finer than what was appropriate for Level IV of the national framework. This dilemma is unresolved in the current set of regions.

The Minnesota Department of Natural Resources (DNR) has had a dedicated ecological region mapping program based on the US Forest Service work by Bailey and others (Bailey et al. 1994, Cleland et al. 1997). The ecological subsections scale of this work, similar to the scale of Level IV ecoregions in the Omernik framework, was developed in collaboration with DNR. DNR has a considerable conservation program that is based on this geographical structure (https://www.dnr.state.mn.us/nr/index.html). The province level of the Forest Service structure is very similar to the Omernik Level III ecoregions in Minnesota. In developing the Level IV ecoregions for Minnesota, the DNR work was quite helpful and by comparing the DNR map of subsections in Appendix M (Map M48) with the Level IV regions from this work overlaid, a number of similarities will be apparent. Because of the use of the DNR regions in the state, it was clear that another set of similarly-scaled regions would be less applicable than if the DNR work did not exist.

5. Descriptions of Level III and Level IV ecoregions

As a general definition in the Omernik framework, ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources; they are designed to serve as a spatial framework for the research, assessment, monitoring, and management of ecosystems and ecosystem components. Special purpose maps of characteristics such as plant communities, water quality, soils, and fish distributions are necessary and have long been used for dealing with specific research and management problems. Ecoregions, on the other hand, portray areas within which there is similarity in the mosaic of all biotic and abiotic components of both terrestrial and aquatic ecosystems. Recognition, identification, and delineation of these multipurpose regions are critical for structuring and implementing integrated management strategies across federal, state, tribal, and local governmental agencies that are responsible for different types of resources within the same geographical areas.

The naming of Level III and Level IV ecoregions was intended to associate place names with a key landscape characteristic descriptive of or unique to the region. Consequently, the ecoregion names (and the map) serve an educational purpose by relating public perceptions to the environment, thus using the concept of "place" and allowing a connection to be made between ecoregions and the general public.

46. <u>Northern Glaciated Plains</u>

Most of the Northern Glaciated Plains Level III ecoregion is located in the eastern Dakotas with two small peninsulas in southwestern Minnesota. It is characterized by a flat to gently rolling landscape composed of glacial drift. The subhumid conditions fostered a grassland transition between the tall and shortgrass prairie, in Minnesota primarily tallgrass prairie. Though the till soil is very fertile, agricultural success is subject to annual climatic fluctuations. The frigid soil regime in this ecoregion contrasts with the mesic temperature regime in Level III ecoregions 47 and 52 to the south and east, and affects, along with higher elevations, the success of agriculture. There are five small Level IV ecoregions in Minnesota.

46e. Tewaukon/BigStone Stagnation Moraine

In Minnesota this ecoregion is a transition from the Red River Valley to the Minnesota River Valley and from the Red River Lobe to the Des Moines Lobe of Wisconsin glaciation. There are many lakes including the long Lake Traverse at the head (south end) of the Red River drainage and the long Big Stone Lake at the head of the Minnesota River, both lakes forming the boundary between South Dakota and Minnesota. The topography is gently undulating and rolling with corn and soybean agriculture throughout the ecoregion except for some wetlands in the southern part of the region near the reservoirs and wetlands along the Minnesota River, and in the southeastern part of the region in former Glacial Lake Benson. There is a ridge of slightly higher elevations running east-west through the ecoregion on top of which and south of which is an area of clayey Udert soils that correlate with alternating till plain and drift complex with rolling topography and some steep slopes. About 70% of this ecoregion was corn and soybeans in 2013, and almost 15% wetlands.

46k. Prairie Coteau

In Minnesota this ecoregion has a small area which is part of the coteau complex consisting of regions 46k, 46l, and 46m. The gently undulating, hummocky landscape has some lakes, and streams draining both northeast to the escarpment (46l) and southwest to the Big Sioux Basin (46m). Corn and soybeans and some pasture are grown on the loamy, well-drained loess soils, mostly moist prairie Udolls. The presettlement vegetation of tallgrass prairie occupied the drift complex of the Bemis moraine of the Des Moines Lobe and the outwash areas in stream channels. About 65% of this ecoregion was corn and soybeans in 2013, and another almost 20% pasture or grassland.

46l. Prairie Coteau Escarpment

This ecoregion is a narrow band of sloping land, rising 90 to 180 m in elevation from the Minnesota River Valley to the brow of the Prairie Coteau (46k). In Minnesota this ecoregion has several streams that cut narrow, relatively straight channels with some riparian vegetation as they descend northeast to the valley, but the interfluve slopes are primarily moist prairie Udolls on glacial till farmed with corn and soybeans and some pasture. About 65% of this ecoregion was corn and soybeans in 2013 and almost 20% pasture or grassland.

46m. Big Sioux Basin

In Minnesota this ecoregion is part of the coteau complex with loess on top of mostly pre-Wisconsin glacial till. Along the northeast border of this region is the Buffalo Ridge, the highest elevation land in southern Minnesota, along most of which windmills have been installed. The ridge is till from the Bemis moraine of the Des Moines Lobe. The soils are mainly loamy, well-drained, moist prairie Udolls farmed with corn and soybeans and some pasture. The former tallgrass prairie matrix was interrupted by wet prairie on outwash in several areas. About 65% of this ecoregion was corn and soybeans and 25% pasture or grassland in 2013.

46o. Minnesota River Prairie
This ecoregion has only a small portion in Minnesota. It is essentially an extension of the Des Moines Lobe (47b); see that description. Almost 60% of this ecoregion was corn and soybeans and over 25% wetlands in 2013.

47. <u>Western Corn Belt Plains</u>
The high agricultural productivity of the Western Corn Belt Plains Level III ecoregion is due to its fertile mesic soils, temperate climate, and adequate precipitation during the growing season. This ecoregion has a relatively homogeneous topography of level to gently rolling glacial till plains with areas of morainal hills and loess deposits. The original tallgrass prairie vegetation has been converted to intensive row crop agriculture of corn, soybeans, and feed grains to support livestock production. This agriculture has been aided by the mesic soils, in contrast with frigid soils in Level III ecoregion 46 and in most of Minnesota north of this ecoregion. There are four Level IV ecoregions in Minnesota.

47a. Loess Prairies
This ecoregion covers the southwest corner of Minnesota and extends south into Iowa and west into South Dakota. In several respects this ecoregion is a continuation of 46m, the Big Sioux Basin, however it differs in having several sections of scoured bedrock uplands close to the surface, about half of the region covered with mesic Ustolls from pre-Wisconsin glaciation till rather than frigid Udolls, and in being slightly warmer and with slightly more precipitation. This is the highest and driest ecoregion in the Western Corn Belt Plains. The topography is a gently undulating plain with a moderate to thick layer of loess. Till plain covers much of the ecoregion with significant channels of outwash along the Rock River and other streams. The eastern half of the ecoregion has mostly moist prairie Udolls from the Des Moines Lobe and the western half has dryer prairie Ustolls from pre-Wisconsin glaciation. The area is mostly treeless, except for the more moist areas along some stream corridors and on farmstead windbreaks. The dominant land use is corn and soybean agriculture with some pasture. Along the eastern border is a continuation of the Buffalo Ridge from Ecoregion 46m, with windmills along the ridge north of Interstate 90. About 75% of this ecoregion was corn and soybeans and 15% pasture or grassland in 2013.

47b. Des Moines Lobe
This ecoregion extends from southern Minnesota into north-central Iowa. It was covered with the Des Moines Lobe of the Wisconsin glaciation (last of the Pleistocene glacial periods) and the topography is level to gently rolling. Along the northwestern border the land rises to meet the coteau complex of Ecoregion 46 and then covers the continuation of the higher elevation land to the south of the coteau proper and east of the Loess Prairies (47a). The northern two-thirds of the ecoregion is bisected by the Minnesota River, from northwest to southeast, and its floodplain that is trenched into the glacial till along much of its length before the river turns northeast at Mankato. Much of the eastern border is formed by moraines from both the Des Moines Lobe glaciation and earlier stages of glaciation. The largest part of the ecoregion is in till plain and ground moraine. A large part of the ecoregion is covered with wet prairie Aquolls, with moist prairie Udolls in several areas in the western part of the region, and a small area of wet, clayey Aquerts in former Glacial Lake Minnesota south of Mankato. There are many lakes in the southern part of the ecoregion. This ecoregion, formerly in tallgrass prairie, is the heart of corn and soybeans agriculture in Minnesota. North of the Minnesota River, from east of the Chippewa River to the town of Winthrop there have been sugar beets mixed in with corn and soybeans. About 75% of this ecoregion was corn and soybeans in 2013.

47c. Eastern Iowa and Minnesota Drift Plains
This ecoregion is geologically complex and is a transition between the bedrock-dominated landforms of the Rochester/Paleozoic Plateau Upland (52b) and the relatively recent glacial drift landforms of the Des Moines Lobe (47b). The eastern half of the ecoregion is covered with pre-Wisconsin glacial till while the western half is till plain and till-covered moraines with outwash from the Des Moines Lobe. The topography is gently undulating to level and formerly was vegetated with tallgrass prairie in the western and eastern parts of the ecoregion and oak savanna in the central part. Soils are a complex pattern of forest soils (Aqualfs and Udalfs)

in the central part of the ecoregion where oak savanna was more dominant, and prairie soils (Aquolls and Udolls) to the east and west, where prairie was more dominant. Row crop agriculture, primarily corn and soybeans, is the dominant land use with pea crops scattered through the area. About 65% of this ecoregion was corn and soybeans and 15% pasture or grassland in 2013.

47g. Lower St. Croix and Vermillion Valleys

This is a small ecoregion with a similar sized section in Wisconsin. The topography is rolling on the higher elevation ridges, to dissected along drainage courses, to flat in the Mississippi River floodplain and in outwash areas on top of the bluffs back from the edge of the floodplain. The former vegetation was tallgrass prairie and the soils are predominantly sandy and loamy well-drained Udolls. Current land use is corn and soybeans with scattered peas, and some pasture and hay. South of Interstate 94 and east of highway 95 much of the bluffs above the dissected stream corridors leading to the St. Croix River are covered with forest. About 50% of this ecoregion was corn and soybeans, 15% pasture or grassland, and 10% deciduous forest in 2013.

48. Lake Agassiz Plain

Glacial Lake Agassiz occupying this Level III ecoregion was the last in a series of proglacial lakes to fill the Red River Valley since the beginning of the Pleistocene. The Lake Agassiz Plain is composed of thick lacustrine sediments underlain by glacial till with till plain at higher elevations in the plains of ecoregion 48d. The physical features of the landscape are all related to the Red River Lobe of the Wisconsin glaciation. The basin itself (48a) is extremely flat and has fewer lakes than neighboring ecoregions. The historic tallgrass prairie has been replaced by intensive agriculture. There are three Level IV ecoregions in Minnesota.

48a. Glacial Lake Agassiz Basin

This ecoregion is split between Minnesota and North Dakota by the Red River of the North. The topography is flat with a very slight declining gradient to the north and, in Minnesota, to the west. Because the Red River has a poorly defined floodplain and very low gradient, flooding can be a problem. The row crop agriculture that has replaced tallgrass and wet prairies varies in crop selection from year to year both because of changes in market demand and because there are relatively low margin crops due to the cooler growing season compared to, for example, ecoregions within the Western Corn Belt Plains (47). In recent years, corn and soybeans have been grown throughout the ecoregion but sugar beets are an important additional crop in several sections. In the northern part of the ecoregion, sugar beets, wheat, and beans are also grown with corn and soybeans. Soils are mostly wet prairie Aquolls with wet clayey Aquerts in the wetter areas; both types of soils are very productive, have high water tables, and have been ditched and drained. There are some localized areas of saline soils (https://www.dnr.state.mn.us/ecs/251Aa/index.html). About 30% of this ecoregion was soybeans, 20% spring wheat, 20% corn, and 10% sugarbeets in 2013.

48b. Beach Ridges and Sand Deltas

The varying relief of the Beach Ridges and Sand Deltas ecoregion interrupts the extremely flat and intensively farmed land of the Glacial Lake Agassiz Basin (48a). The beach ridges appear as parallel lines, running generally north-south, of sand and gravel formed by wave action on the varying shoreline levels of Glacial Lake Agassiz. A high erosion risk exists in the sand dune areas, and gravel mining has altered the gravelly soils of the beach ridges. Soil types include prairie soils of wet Aquolls, moist Udolls, plus wet, clayey Aquerts, and wet, sandy Aquents. Land use is a mixture of mixed row crops and small grains in several sections, with woody wetlands and deciduous woods dominant in others, all replacing the presettlement vegetation of tallgrass and brush prairie, and aspen stands. About 25% of this ecoregion was wetlands, 20% soybeans, and 10% spring wheat, 9% deciduous forest, 9% other hay crops in 2013.

48d. Lake Agassiz Plains

This ecoregion is more similar to the basin ecoregion (48a) than to the ridges ecoregion (48b) in that it is primarily flat but 30 to 90 m higher in elevation than the basin, and separated by the ridges of 48b. Soils are predominantly moist prairie Udolls and dry prairie Ustolls with an area of moderately decomposed Hemists bog in the north of the ecoregion. The tallgrass and wet prairies, and sections of aspen parkland have been replaced by corn, soybeans, and some sugar beets, in the southern part, and by mixtures of row crops, small grains, and pasture and hay in the northern part. The southern part is mostly till plain whereas the northern part is lacustrine, similar to the Glacial Lake Agassiz Basin (48a). About 25% of this ecoregion was wetlands, 25% soybeans, 12% spring wheat, 10% corn, and 9% deciduous forest in 2013.

49. <u>Northern Minnesota Wetlands</u>

Much of the Northern Minnesota Wetlands Level III ecoregion is a vast and nearly level wetland that is sparsely inhabited by humans and covered by conifer bog, mixed forest, and boreal forest vegetation. Formerly occupied by broad glacial lakes, much of the flat terrain in this ecoregion is still covered by standing water. Some low-gradient streams and eroded river channels occur in the east. There are two Level IV ecoregions.

49a. Peatlands

This ecoregion is one of the largest areas of contiguous wetland in the conterminous US. Much of the wetland is peat with corresponding Hemists and Saprists, moderately and completely decomposed organic soils. The peat is interspersed with less organic lacustrine areas of wet forest Aqualfs, wet, sandy Aquents, and small areas of sandy Psamments. Landforms of the peatlands include raised bogs, water tracks, and spring-fen channels. These basic types are combined in various ways, and develop ecologically in different patterns (Glaser 1992a, 1992b). The climate, being cold (Lake of the Woods frequently claims the coldest temperatures in the conterminous US), and the soils, being frigid and wet, limits crops. Much of the peatland and interspersed areas of wet forest and brushland has not changed since Europeans arrived, although there were many attempts in the early 20th Century to construct ditches across the peatlands to prepare the land for agriculture (Bradof 1992). Many of the ditches were abandoned after failed attempts at settlement by farmers. There is today evidence of attempts to clear and plant land, particularly southwest of Lake of the Woods and just south and east of Lake of the Woods along the Rainy River.

Lakota Sioux occupied the peatlands before the arrival of European settlers into North America in the 17th Century. The Red Lake Ojibwe succeeded the Lakota Sioux as the European settlers pushed the indigenous groups to the west from the East Coast of the continent. The indigenous peoples used many of the plants and animals of the peatlands for food, clothing, and other cultural uses (Whelan 1992). Lands of the Red Lake Nation, the only indigenous group in Minnesota whose lands avoided allotment into private property and whose lands are held in common, cover slightly less than 20% of the ecoregion. These indigenous people still continue some of their tribal customs and ways of life combined with partial participation in the external capitalist economy (Meyer 1992). About 75% of this ecoregion was wetlands and 15% open water in 2013.

49b. Forested Lake Plains

This ecoregion, to the east and partially south of the Peatlands (49a), grades from sections of peat in the northwest to more forest in the northeast and forest along the undulating lobes of the wider southern part. Hemists soils are interspersed in small patches in a number of sections between larger areas of wet forest Aqualfs, and forest Udalfs which predominate in the south. The topography is relatively flat with a gentle rising gradient from the Rainy River on the northern border to elevations as much as 75 m higher in the south. There is some evidence of human landscape modification of vegetation but most land is forest or bog except for some cleared land along the Rainy River and south of it for 15 to 20 km along its tributaries, the Big and Little Fork Rivers, and in the area around International Falls. About 60% of this ecoregion was wetlands and 25% deciduous forest in 2013.

50. <u>Northern Lakes and Forests</u>

This Level III ecoregion has relatively nutrient-poor glacial soils, coniferous and northern hardwoods forests, undulating till plains, morainal hills, broad lacustrine basins, and areas of extensive sandy outwash plains. Soils are formed primarily from sandy and loamy glacial drift material and generally lack the arability of those in adjacent ecoregions to the south and west. Ecoregion 50, along with the Lake Agassiz Plain (49), have lower annual temperatures and a frost-free period that is considerably shorter than other ecoregions in Minnesota; this ecoregion also has the largest annual snowfall and the most days with snow cover. These conditions generally hinder agriculture; therefore, woodland and forest are the predominant land use/land cover. Numerous lakes dot the landscape. There are ten Level IV ecoregions in Minnesota.

50a. Lake Superior Clay Plain
There is only a small part of this ecoregion in Minnesota. It is the bed of former Glacial Lake Superior with a plain gently sloping toward Lake Superior but now strongly dissected by the gorges of the Nemadji River as it flows into Wisconsin, and by the lower reaches of the St. Louis River before it enters Lake Superior at Duluth/Superior. The soils are forest Udalfs in the river slopes and bottoms, and sandy forest Orthods and wet forest Aqualfs in the uplands. The presettlement vegetation in the lower Nemadji basin was a mix of white pine, spruce, fir, and aspen; in the rest of the ecoregion it was a complex of patches of white pine and hardwoods, white pine and red pine, aspen-birch, and conifer bogs. Land use and cover today is mainly forest of hardwoods and some conifers, wetlands, and small patches of hay. About 60% of this ecoregion was deciduous and evergreen forest and 20% wetlands in 2013.

50b. Minnesota/Wisconsin Upland Till Plain
The majority of this ecoregion is in Minnesota, with an arm extending into Wisconsin. The large Mille Lacs Lake is a dominant feature in the center of the Minnesota portion of the ecoregion. There are major areas of drumlins interspersed with peatlands northeast of Mille Lacs Lake in Aitken and Carlton Counties, in the western lobe of the ecoregion between Brainerd, Harding, and Fort Ripley, and south of Mille Lacs Lake in Mille Lacs and Kanabec Counties. Other areas are a mix of till plain, sand plain, and moraines. There is a noticeable sharp change of elevation of about 60 m along a straight line from Carlton in the northeast, to where the Snake River flows south out of the higher elevations about 25 km north of Mora. This line may be associated with the one billion year-old Mid-Continent Rift, although the rocks of that era are now covered by sedimentary rocks whose western boundary is close to this line through Carlton, Pine, and northern Kanabec Counties. Southeast of this line there are few drumlin features but areas of peatland interspersed with drift complex. The peatlands are mostly on moderately decomposed Hemist soils with forest Udalfs covering large areas along with lesser areas of less developed forest Udepts and sandy forest Orthods in the sandy areas. The presettlement vegetation was a relatively fine-grained mixture of conifer bogs and swamps, aspen and birch, mixed white and red pine, hardwoods south of Mille Lacs Lake, and small areas of jack pine barrens. The ecoregion is currently covered primarily with deciduous forest and wetlands with only small amounts of cropland west of Mille Lacs Lake and in a few other areas. About 40% of this ecoregion was deciduous forest, 40% wetland, and 8% open water in 2013.

50m. Mesabi Range
This ecoregion is distinctive in Minnesota, and one of its best known areas because of the iron mining that, along with two other nearby areas, has provided much of the iron ore for the United States in the last 130 years. The heart of the ecoregion is a narrow range of hills or mountains of exposed Archaen rocks 60 to 90 m above the surrounding area in a line from near Grand Rapids in the southwest to Babbit, about 130 km east-northeast. The iron ore mines in these hills have produced over three billion metric tons of iron ore and have considerable remaining potential deposits, depending upon prices and technology. Adjacent to the southeast of the iron range is a series of copper, nickel, and platinum deposits that are largely undeveloped. The copper resource has the highest value of embodied energy of any natural resource in the state, about five times that of nickel, and about ten times that of the remaining iron ore (Campbell and Ohrt 2009, Table 8). The presettlement vegetation was mixed hardwoods and pines in the higher elevations and aspen and birch with patches of conifer bogs and swamps elsewhere. There are now large areas of land barren from mining or full of water in open pits. Most of the remaining area is mixed forest with some shrub and grassland. About 40% of this ecoregion was deciduous and mixed forest, 17% wetlands, and 12% barren in 2013.

50n. Boundary Lakes and Hills
This ecoregion is well known for its many lakes and rivers and undisturbed landscape, providing innumerable canoe and kayak and camping recreation opportunities. Comprising a large area in northeastern Minnesota adjacent to a similar landscape in Ontario, the ecoregion is an extension of the Archaen and Proterozoic

bedrocks of the Canadian Shield with scoured bedrock uplands covered by a thin layer of less developed forest Udept soils. The ecoregion has the highest single elevation in Minnesota (about 700 m) and a large area of high elevation in the eastern part of the ecoregion; the terrain is rolling to undulating with some steep slopes. The presettlement vegetation was jack pine, white and red pine, spruce, fir, birch and aspen forest. Mixed deciduous and evergreen forest and many lakes cover the ecoregion today. The ecoregion hosts Voyageurs National Park in the northwest and the Boundary Waters Canoe Area Wilderness (BWCAW) over much of the rest of the northern half of the ecoregion. BWCAW covers about 36% of the ecoregion. Heinselman's book (1966) has described the BWCAW in great detail: the history and current status of climate, fire, logging, and human culture, as well as that of the vegetation, fauna, landscape ecology, and the legislation covering the area. Fire was an important component of the structure of the BWCAW over time until logging and fire suppression began in the 20th Century. This ecoregion has the highest number of lakes among all Level IV regions. About 55% of this ecoregion was mixed, evergreen, and deciduous forest, 25% wetlands, 15% open water in 2013.

50o. Glacial Lakes Upham and Aitkin
This ecoregion is primarily in a distinctive former glacial lake bed that is mostly flat peatlands and flat to gently rolling lake plains and till plains. The Mississippi River flows through the ecoregion and in the southern part of the ecoregion occurs the only small area of agriculture, in patches within 7 km of the river. The vast majority of the region is now woody wetland with several areas and small patches of non-wetland forest. The presettlement vegetation was heavily covered with conifer bogs and swamps with aspen and birch along the St. Louis River in the center of the ecoregion and in many patches elsewhere, plus smaller amounts of white and red pine. The peatlands are primarily on moderately decomposed Hemists, with sections of sandy forest Psamments, wet forest Aqualfs near the St. Louis and Mississippi Rivers, and forest Udalfs in a few places. About 60% of this ecoregion was wetlands and 25% mixed and evergreen forest in 2013.

50p. Toimi Drumlins
This ecoregion in the northeastern Minnesota "Arrowhead" region was formed by till plains, drumlins, moraines, and peatlands from the Rainy and Superior lobes of the Wisconsin glaciation (last of the Pleistocene glacial periods). Much of the central western part of the ecoregion is a northeast-southwest trending drumlin field of alternating woody wetlands in the plain and dryer mixed forest on the drumlin ridges. The land cover in the rest of the ecoregion is also a mixture of patches of forest and wetland with numerous lakes, but with less of a ridge and valley structure as in the drumlin field. The topography is rolling with some steep slopes in the drift complex that covers part of the southeastern section of the ecoregion. Presettlement vegetation was similar to Ecoregion 50o, with smaller patches and less area in conifer bogs and swamps and more in white and red pine, and more in aspen and birch. The soils are less developed forest Udepts with a number of patches of peatland Hemists. The Cloquet River flows through the center of the ecoregion until it meets the St. Louis River near the southwestern border, following the strong gradient in elevation from near 610 m in the northeastern end to about 365 m in the southwestern. About 50% of this ecoregion was wetlands and 40% deciduous, mixed, and evergreen forest in 2013.

50q. Itasca and St. Louis Moraines
This ecoregion is moraine country. Multiple moraines from several glacial lobes, the Wadena Lobe in the west and the Rainy and St. Louis Lobes in the east, cover the area. There are also a drumlin field, outwash areas, till plains, lacustrine and drift complex areas on a topography with many short but steep slopes. The ecoregion is primarily covered with well to excessively drained forest Udalf soils with significant areas of sandy forest Psamments, smaller areas of moist but well drained Udoll prairie soils in the west, and somewhat poorly drained wet Aqualfs in the east. The Udolls support the only relatively intense agriculture but there are scattered areas of crops and pasture in the western part of the southern lobe of the ecoregion. The rest of the ecoregion is primarily forest and wetland intermixed with many lakes, the second highest number of lakes among all Minnesota's Level IV ecoregions. The lake region from Leech Lake in the north to Brainerd in the south is part of Hart and Ziegler's "Lakeshore Resort and Retirement Belt" (Hart and Ziegler 2008). Presettlement vegetation was a mosaic of aspen and birch, jack pine barrens, white and red pine, small patches of hardwoods, and small patches of conifer bogs and swamps. This ecoregion has the highest elevations in northwest Minnesota, about 580 m in southwest Clearwater County. The low elevations are about 365 m near

the Mississippi River that forms the southeastern boundary. About 60% of this ecoregion was deciduous and evergreen forest, and 25% wetlands and open water in 2013.

50r. Chippewa Plains

The soils of this ecoregion provide an initial overview. The central east-west belt of the ecoregion is dominated by sandy forest Psamments with most of the northern and southern areas surrounding the Psamments being well-drained forest Udalfs. Patches of moderately decomposed Hemists and two patches in the east of the ecoregion of somewhat poorly drained forest Aqualfs are other noticeable soils. The geomorphology supports the soils patterns with considerable outwash in the central area and till plain, drift complex, moraines, and peat in surrounding areas, on terrain that varies from level to rolling to undulating to hummocky. There are several large lakes, and the upper reaches of the Mississippi River flow through the center of the ecoregion in the sandy outwash areas. The density of lakes by area is among the highest in the state. Presettlement vegetation was a complex mixture of aspen and birch, jack pine barrens, white and red pine, hardwoods, and conifer bogs and swamps. Land use is primarily a mosaic of forest and wetland with some hay and alfalfa agriculture at the western edge and in a small area just east of Bemidji. Hart and Ziegler (2008) include the area around Bemidji and around the lakes to the east and north in their "Lakeshore Resort and Retirement Belt." Compared with ecoregion 50q, the Chippewa Plains have colder winters, warmer summers, fewer numbers of lakes but greater area in lakes, primarily formed from ground and stagnation moraines rather than end moraines, and a less steep topography. About 50% of this ecoregion was deciduous, evergreen, and mixed forest, 30% wetlands, and 13% open water in 2013.

50s. Nashwauk/Marcell Moraines and Uplands

The landscape of this ecoregion was formed by deposits of several lobes of the Wisconsin glaciation, the Rainy Lobe in the east, the Koochiching Lobe in the west, and Wadena Lobe in the small southern lobe of the ecoregion. The deposits include till, drift complexes, moraines, organic deposits that became peat, outwash, and lacustrine deposits from pieces of Glacial Lake Agassiz. The topography is primarily rolling to undulating with steep slopes in outwash areas. The soils in the eastern part of the Rainy Lobe deposits are less developed forest Udepts with patches of moderately decomposed Hemists and sandy forest Psamments, similar to soils in Ecoregions 50n and 50p. In the rest of the ecoregion well drained forest Udalf soils and somewhat poorly drained forest Aqualf soils dominate with patches of Psamments and Hemists interspersed. As with many Northern Lakes and Forests ecoregions, the land cover is forest, wetlands, and lakes, and the density of lakes in the western part of the ecoregion is quite high. The presettlement vegetation was similar to Ecoregions 50p, 50q, and 50r, namely, a mosaic of aspen and birch, white and red pine, jack pine barrens, and conifer bogs and swamps. About 50% of this ecoregion was deciduous, mixed, and evergreen forest and 35% wetlands in 2013.

50t. North Shore Highlands

A distinctive and popular ecoregion of Minnesota, the Minnesota shore of Lake Superior is a spectacular landscape of shoreline ascending to high bluffs for most of the ecoregion from Duluth for over 220 km to the Canadian border. The shore of Lake Superior is the lowest elevation in Minnesota, about 180 m, and the highest point in Minnesota, Eagle Mountain at 700 m in Ecoregion 50n, is only about 24 km from the shore. Land cover is largely mixed forest and shrubland with numerous small wetlands, few lakes, and little if any agriculture. The upland rural areas in the ecoregion north of Duluth to around Two Harbors have homesites and some cleared land for hay and pasture. The shore itself has many resorts and campgrounds and is a well developed tourist area. The presettlement vegetation was primarily white and red pine in the southern half and aspen and birch in the northern half with scattered patches of conifer bog and swamp. Close to the shore the soils are forest Udalfs, and poorly developed, shallow Orthents; in the upland the soils are less developed forest Udepts. The landscape formed from the Superior Lobe of the Wisconsin glaciation and is primarily till plain with scoured bedrock upland in the central and far northern parts of the ecoregion. This ecoregion, along with the Blufflands and Coulees (52b), is one of the two areas in Minnesota that support cold water lakes and streams with trout populations, although the native trout have now largely been replaced by introduced salmonid species that are either better suited to current conditions, or out-compete the native species. About 75% of this ecoregion was deciduous, evergreen, and mixed forest and 15% wetlands in 2013.

51. <u>North Central Hardwood Forests</u>
This Level III ecoregion is transitional between the predominantly forested Northern Lakes and Forests (50) to the north and the Western Corn Belt Plains (47) to the south and the Lake Agassiz Plain (48) to the west. Nearly level to rolling till plains, lacustrine basins, outwash plains, and rolling to hilly moraines comprise the physiography of this ecoregion. The land use and land cover in this ecoregion consists of a mosaic of deciduous forests, wetlands and lakes, cropland agriculture, pasture, and dairy operations. This ecoregion also contains the large urban metropolis of Minneapolis and St. Paul. The growing season is generally longer and warmer than that of Ecoregion 50 to the north, and the soils are more arable and fertile, contributing to the greater agricultural component of the land use. Lake densities are generally lower here than in the Northern Lakes and Forests but greater than in agricultural ecoregions south and west. There are six Level IV ecoregions in Minnesota.

51a. St. Croix Stagnation Moraines
In Minnesota this ecoregion is small and dominated by the Twin Cities metropolitan area. The Mississippi River is joined by the Minnesota River about 10 km below St Anthony Falls in Minneapolis. The topography is rolling to level on outwash terraces and end moraine with some steep slopes on the moraine edges. The soils are forest Udalfs and moist prairie Udolls on which the land use is urban and suburban in much of the ecoregion and mixed row crops and woods to the north and east of the Twin Cities toward the Wisconsin border. The presettlement vegetation was primarily oak openings and savanna and patches of hardwoods. About 22% of this ecoregion was suburban low intensity development, 20% medium and high intensity development, 17% deciduous forest, 11% developed open space, 10% pasture or grassland, and 7% open water in 2013.

51h. Anoka Sand Plain and Mississippi Valley Outwash
This ecoregion is dominated by a sandy lake plain and terraces along the Mississippi River. The sand plain formed from outwash from the Mississippi River when it was blocked near St. Cloud by the Grantsburg lobe of the Wisconsin stage of glaciation and formed a course to the east, until it later developed drainage to the south in its present course. The presettlement vegetation was primarily oak openings and savanna in the sandy areas with an area of wet prairie in the eastern part of the ecoregion and with prairie on the terraces near the Mississippi. The soils are sandy forest Psamments in the extensive sandy areas with moist prairie Udolls on the terraces, moderately decomposed Hemists in the formerly wet prairie area, and small patches of forest Udalfs in the center of the ecoregion. Much of the southern half of the ecoregion is covered with sections of suburban development for the Twin Cities. The terraces north of Elk River are largely crop land; the former wet prairie is mainly bog with patches of aspen or other hardwoods. The rest of the northern part of the ecoregion is a mixture of row crops, pasture and hay, and woods. About 25% of this ecoregion was wetlands, 25% deciduous forest, and 20% in corn and soybeans in 2013.

51i. Big Woods
This is a distinctive ecoregion in southern Minnesota in its presettlement vegetation and soils. This was an island of oak, maple, basswood and other hardwoods surrounded by prairie and savanna. The woods had many small patches of wet prairie and a number of lakes. The moraines that cover the area have a rolling topography. The predominant soil suborder is forest Udalfs with a patch of wet prairie Aquolls in the southern part of the ecoregion. Within a radius of 30 to 45 km from the center of Minneapolis this ecoregion is a mixture of suburban development, lakes, woods, and pasture. In the rest of the ecoregion there are several sections of corn and soybean agriculture and other sections of mixtures of row crops, woods, lakes and pasture. About 40% of this ecoregion was corn and soybeans, 15% deciduous forest, 15% developed, 13% wetlands, 7% pasture or grassland, and 7% open water in 2013.

51j. Alexandria Moraines and Detroit Lakes Outwash Plain
This lengthy ecoregion is in the western part of the state bordering the Lake Agassiz Plain (48) to the west. The southern section is about 200 km long from slightly west of north to sightly east of south and 30 to 50 km wide. The section north of Detroit Lakes is shaped like a finger pointing east and is about 130 km long and 8 to 14 km wide. The topography is a complex of rolling knobs and kettles in the moraine and outwash landscape. The

southern section is mainly moist prairie Udolls formerly covered with tallgrass prairie, hardwoods, and savanna, and the northern section mainly forest Udalfs formerly covered with a mix of patches of hardwoods, oak openings, aspen and birch, and pines. There are several areas of concentrated corn and soybean agriculture but most of the southern part of the ecoregion has interspersed patches of deciduous forest, lakes, wetlands, crops (mainly corn, soybeans, alfalfa), and pasture, while the northern part has mainly deciduous forest, lakes, and alfalfa. The southern section of the ecoregion is part of what Hart and Ziegler call "The Lakeshore Resort and Retirement Belt" (Hart and Ziegler 2008) with many retirement and second homes especially near the many lakes. About 27% of this ecoregion was corn and soybeans, 24% deciduous or evergreen forest, 13% open water, 11% pasture or grassland and 10% wetlands in 2013.

51k. McGrath Till Plain and Drumlins

This ecoregion is a transition from hardwood forest and hay farming in the north to corn and soybeans farming in the south. The topography is undulating and gently rolling with sections of elongated hills or drumlins; elevations vary from around 300 m in the river valleys in the east and south to 400 m or more in the northwest, but varies in the northern section from lower elevation outwash areas to higher elevation glacial drift. The presettlement vegetation was prairie in the southwest, aspen-oak woodlands and oak openings and savanna in the southeast, and hardwoods and aspen-oak woodlands in the north (north of the Sauk River). The soils in the north are primarily forest Udalfs, and a mix of Udalfs and moist prairie Udolls in the south. There are few lakes in this ecoregion. This ecoregion is entirely in the "Dairy Belt" of Hart and Ziegler (2008) where, especially in the northern section, the rolling topography is more likely to be planted with hay crops which then provide feed for dairy cattle. About 30% of this ecoregion was corn and soybeans, 20% deciduous forest, and 20% wetlands in 2013.

51l. Wadena/Todd Drumlins and Osakis Till Plain

This ecoregion between the Alexandria Moraines (51j) and the McGrath Till Plain (51k) has similarities to both. The topography is gently rolling with sections of drumlins as in 51k but the elevations are primarily in the 400s of meters as in 51j. The soils are moist prairie Udolls in the southern quarter of the ecoregion and in patches along the western border; forest Udalfs in a large section in the center of the ecoregion and another patch in the northwest; and a substantial section of sandy forest Psamments in the northeast. The moist prairie Udolls soils in the southern quarter are primarily used for corn and soybean farming, but the rest of the ecoregion is a mixture of small sections of cropland (corn, soybeans, dry beans, some of it irrigated) in a matrix of deciduous woods, alfalfa and other hays, and wetlands. The southern three-fourths of the ecoregion is in the Hart and Ziegler (2008) Dairy Belt. About 25% of this ecoregion was corn and soybeans, 25% deciduous and evergreen forest, and 20% wetlands in 2013.

52. Driftless Area

The hilly uplands of the Driftless Area Level III ecoregion easily distinguish it from surrounding ecoregions. Much of the area consists of a deeply dissected loess-capped plateau. The ecoregion is also called the Paleozoic Plateau because the landscape’s appearance is a result of erosion through rock strata of Paleozoic age. Although evidence of more recent glacial drift has been found in this ecoregion, its influence has been minor compared to surrounding ecoregions. In contrast to the adjacent glaciated ecoregions, the Driftless Area has few lakes, and a stream density and flow that is generally greater than neighboring ecoregions. Hart and Ziegler (2008) include this region in their Dairy Belt. There are two Level IV ecoregions in Minnesota.

52b. Blufflands and Coulees

The bedrock-dominated terrain of this ecoregion is strikingly different from the rest of Minnesota. The topography is a highly dissected landscape of steep ravines (coulees) heading generally east down to the Mississippi River from the plateau to the west (Ecoregion 52c), and descending in multiple directions from ridgetops and bluffs directly above coulees. Much of the picturesque quality of this ecoregion comes from the contrast between the Ordovician sandstone, limestone, and shale bedrock forming much the bluffs and ridgetops, and the steep walls and flat bottoms of the valleys. Soils on the bluffs and ridgetops are loess as Udalfs; alluvium as sandy Psamments or Aquents, or flood-prone Fluvents in the valley bottoms; and rockier soils on the slopes. Presettlement vegetation was oak openings and savanna in the northern and southwestern parts of the ecoregion and diverse hardwoods in the southern part. Contemporary land use is mixed crops and pasture and hay both on the bluffs and ridgetops, and in the valley bottoms, with hardwoods on the slopes. This ecoregion, along with the North Shore Highlands (50t), is one of the two areas in Minnesota that support cold water lakes and streams with trout populations, although the native trout have now largely been replaced by introduced salmonid species that are either better suited to current conditions, or out-compete the native species. About 40% of this ecoregion was deciduous forest, 25% pasture or grassland, and 20% corn and soybeans in 2013.

52c. Rochester/Paleozoic Plateau Upland
This ecoregion is a transition between the highly dissected landscape of the Bluffland and Coulees (52b) and the Eastern Iowa and Minnesota Drift Plains (47c) of the Western Corn Belt Plains. As in Ecoregion 52b the geomorphology is based on pre-Wisconsin glaciation. The topography is gently rolling and the soils are primarily forest soils (Udalfs) in the northern part and a mix of forest Udalfs and moist prairie Udolls in the southern part; loess grades from thin in the western edge of the ecoregion to thicker at the boundary with Ecoregion 52b. The landscape at presettlement was a mixture of tallgrass prairie, brush prairie, and oak openings and savannas. The land today is extensively farmed with row crops, primarily corn and soybeans, and some pasture and hay. About 45% of this ecoregion was corn and soybeans, 30% pasture or grassland, and 9% deciduous forest in 2013.

6. Acknowledgments

The inspiration for and help with the development of the ecological regions of Minnesota have come from colleagues in this work, especially Jim Omernik who started and has led this work, Glenn Griffith who has participated in the development of many of the state by state projects and also led the development of three levels of ecoregions for South and Central America (Griffith et al. 1998), and Alan Woods who also has participated in many of the state projects.

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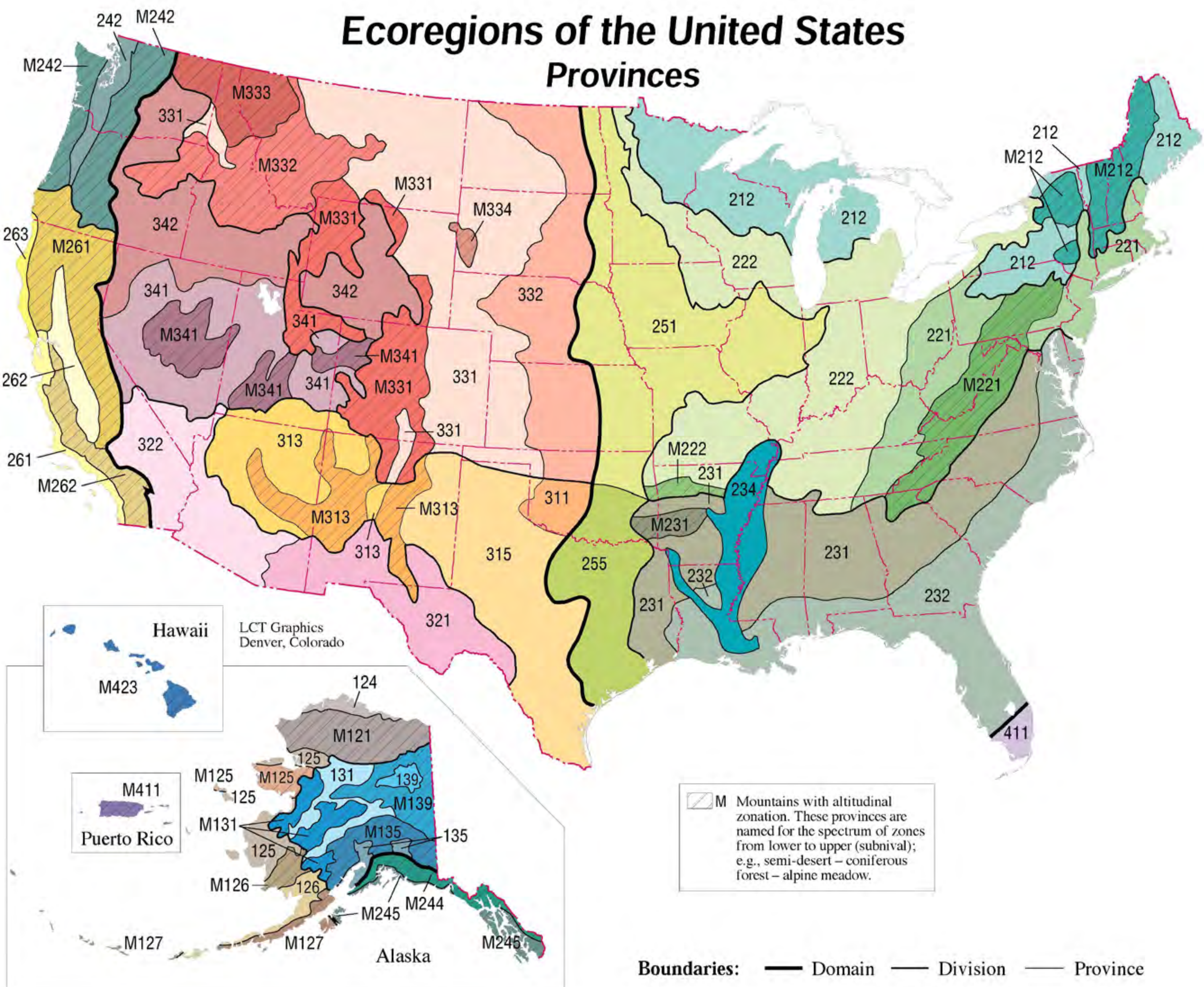

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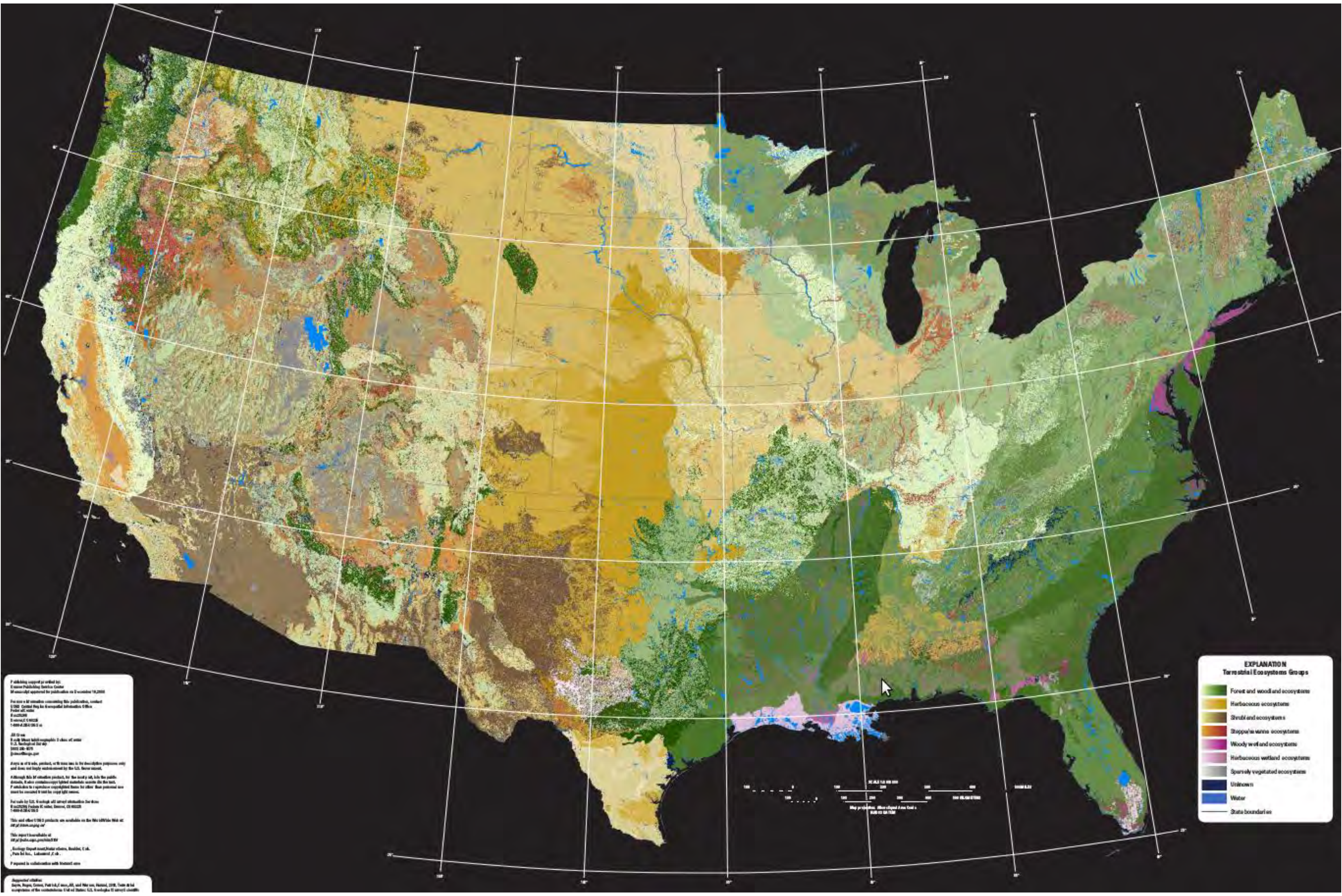
419 NatureServe Ecosystems



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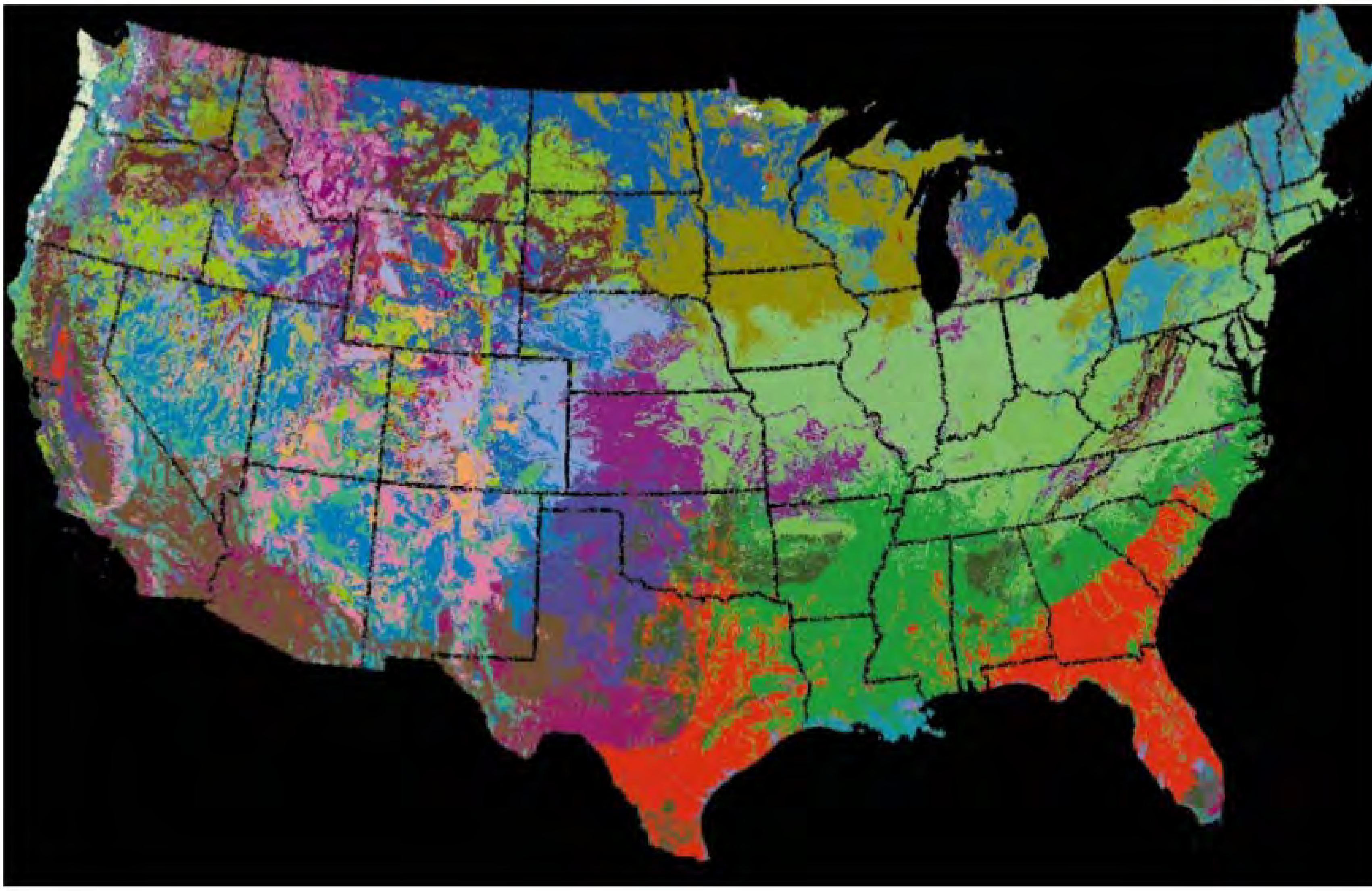
Hargrove

50 Ecoregions created from Clustering Nine Variables



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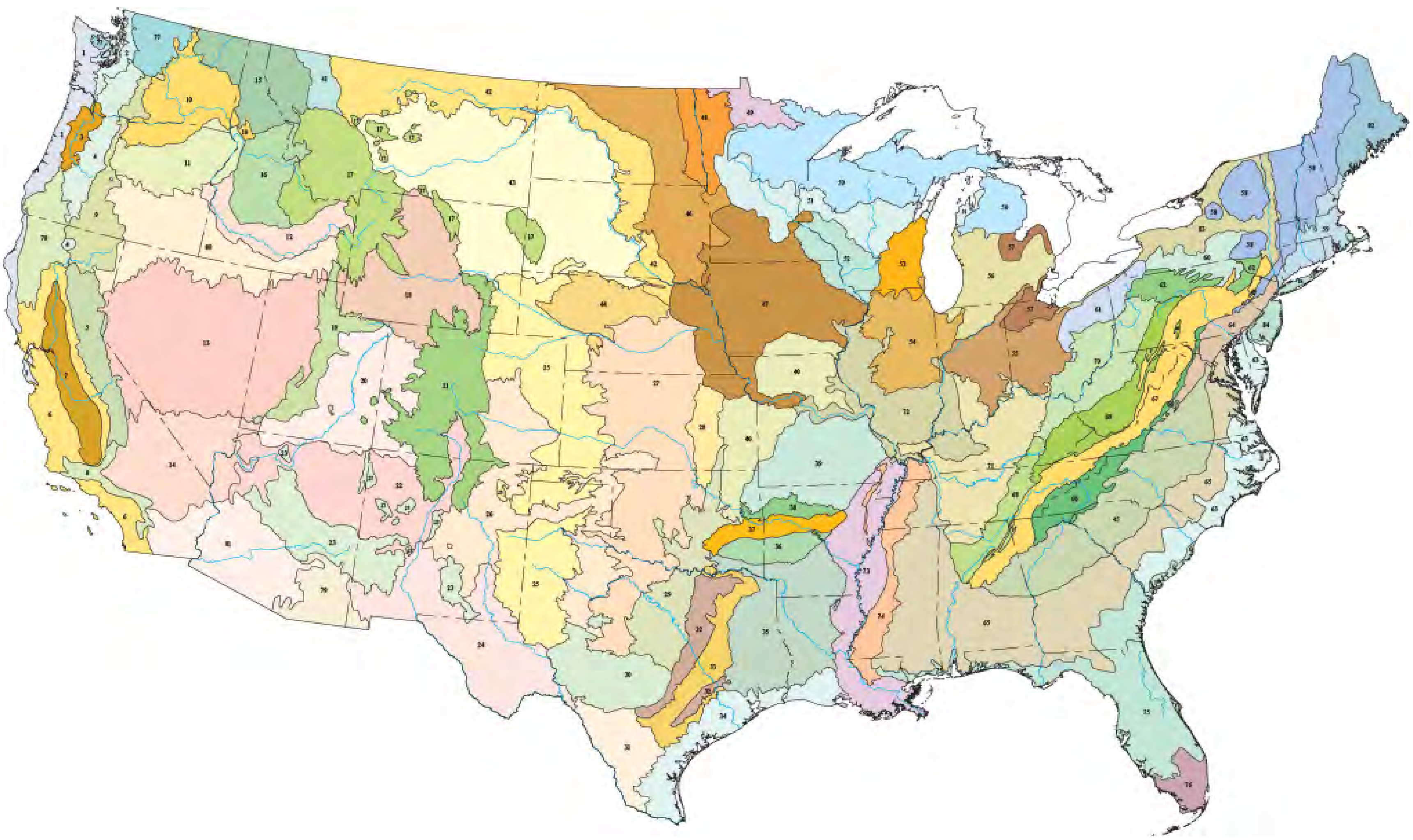
Level III Ecoregions, 1987-2016



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Appendix F

Minnesota Flora and Fauna Species Counts

Native Species
From Tester 1995, Appendices B through G

Trees	45	
Shrubs	59	
Herbs	292	
Mussels	50	
Mammals	80	
Birds breeding	251	
Reptiles	29	
Amphibians	19	
Fishes	19	(From https://www.dnr.state.mn.us/fish/index.html)

Invasive Species
From https://www.dnr.state.mn.us/invasives/index.html

Aquatic animals	18
Aquatic plants	>= 9
Terrestrial animals	12
Terrestrial plants	>= 300

Species of Concern
From: *Minnesota's List Of Endangered, Threatened, And Special Concern Species*, Minnesota Department of Natural Resources, 2013

Amphibians/Reptiles	16
Birds	32
Butterflys/Moths	19
Caddisflys	24
Dragonflys	8
Fishes	34
Fungi	8
Jumping Spiders	10
Leafhoppers	3
Lichens	37
Mammals	21
Mollusks	33
Mosses/Liverworts	27
Tiger Beetles	9
Vascular Plants	309

Appendix L

Percentages of Land Cover and Land Use by Level IV Ecoregion in 2013

The percentages of land cover and land use by Level IV ecoregion were calculated from the 30 meter pixel layer of the 2013 Cropland Data Layer (CDL) prepared by the US Department of Agriculture National Agricultural Statistical Service (USDA NASS 2015). The CDL has predictions of crops at each pixel in agricultural areas of Minnesota. Pixels for all non-agricultural areas of the state are populated with data from the US Geological Survey's National Land Cover Database for 2006.

These agricultural crop and non-agricultural land use and landcover data were isolated for each Level IV ecoregion and summarized by percentage of land in the ecoregion. The isolation process (a GIS process of combining the polygons of the ecoregions with the pixels of the CDL) has possible errors due to the conversion of the ecoregion data to pixels matching the size and position of the CDL, minor registration errors between the two datasets, and inevitable rounding that occurs in such a process. About 0.11 percent of the pixels did not properly get isolated to a correct ecoregion and are thus missing in the results. The final percentages were rounded to the nearest integer percent, and only those classes that had at least one percent of the total in the ecoregion after rounding are included in the table for that ecoregion.

46e Tewaukon/Big Stone Stagnation Moraine

%	Class
38	Corn
29	Soybeans
14	Herbaceous Wetlands
5	Developed/Open Space
5	Open Water
2	Grassland/Pasture
2	Spring Wheat
1	Deciduous Forest
1	Dry Beans
1	Sugarbeets
1	Alfalfa

46k Prairie Coteau

%	Class
35	Corn
30	Soybeans
19	Grassland/Pasture
5	Developed/Open Space
3	Herbaceous Wetlands
3	Open Water
1	Deciduous Forest
1	Alfalfa
1	Spring Wheat

46l Prairie Coteau Escarpment

%	Class
36	Corn
32	Soybeans
18	Grassland/Pasture
4	Herbaceous Wetlands
4	Developed/Open Space
2	Deciduous Forest
2	Alfalfa
1	Spring Wheat

46m Big Sioux Basin

%	Class
39	Corn
26	Grassland/Pasture
25	Soybeans
5	Developed/Open Space
3	Alfalfa
1	Herbaceous Wetlands
1	Deciduous Forest
1	Spring Wheat

46o Minnesota River Prairie

%	Class
30	Soybeans
29	Corn
27	Herbaceous Wetlands
4	Developed/Open Space
3	Open Water
2	Grassland/Pasture
1	Woody Wetlands
1	Deciduous Forest
1	Alfalfa
1	Spring Wheat

47a Loess Prairies

%	Class
45	Corn
31	Soybeans
14	Grassland/Pasture
5	Developed/Open Space
1	Herbaceous Wetlands
1	Deciduous Forest
1	Developed/Low Intensity
1	Alfalfa

47b Des Moines Lobe

%	**Class**
45	Corn
30	Soybeans
7	Herbaceous Wetlands
5	Developed/Open Space
3	Grassland/Pasture
2	Deciduous Forest
2	Open Water
1	Woody Wetlands
1	Developed/Low Intensity
1	Sugarbeets
1	Alfalfa
1	Sweet Corn

47c Eastern Iowa and Minnesota Drift Plains

%	**Class**
34	Corn
30	Soybeans
16	Grassland/Pasture
6	Developed/Open Space
3	Deciduous Forest
3	Peas
2	Sweet Corn
1	Herbaceous Wetlands
1	Woody Wetlands
1	Developed/Low Intensity
1	Open Water
1	Alfalfa

47g Lower St. Croix and Vermillion Valleys

%	**Class**
32	Corn
18	Soybeans
15	Grassland/Pasture
10	Deciduous Forest
6	Developed/Open Space
3	Developed/Low Intensity
3	Open Water
3	Peas
2	Herbaceous Wetlands
2	Developed/Medium Intensity
2	Alfalfa
1	Woody Wetlands
1	Developed/High Intensity
1	Sweet Corn

48a Glacial Lake Agassiz Basin

%	**Class**
31	Soybeans
20	Spring Wheat
20	Corn
10	Sugarbeets
5	Developed/Open Space
4	Herbaceous Wetlands
2	Woody Wetlands
2	Open Water
1	Grassland/Pasture
1	Deciduous Forest
1	Developed/Low Intensity
1	Dry Beans
1	Other Hays
1	Alfalfa

48b Beach Ridges and Sand Deltas

%	**Class**
24	Herbaceous Wetlands
19	Soybeans
10	Spring Wheat
9	Deciduous Forest
9	Other Hays
7	Corn
5	Woody Wetlands
4	Developed/Open Space
4	Alfalfa
2	Open Water
1	Grassland/Pasture
1	Developed/Low Intensity
1	Fallow/Idle Cropland
1	Sugarbeets
1	Winter Wheat
1	Barley

48d Lake Agassiz Plains

%	**Class**
25	Herbaceous Wetlands
25	Soybeans
12	Spring Wheat
10	Corn
9	Deciduous Forest
4	Developed/Open Space
3	Alfalfa
2	Woody Wetlands
2	Grassland/Pasture
2	Open Water
2	Other Hays
1	Developed/Low Intensity
1	Seed/Sod Grass
1	Sugarbeets
1	Barley

49a Peatlands

%	**Class**
50	Woody Wetlands
24	Herbaceous Wetlands
15	Open Water
4	Deciduous Forest
2	Soybeans
1	Developed/Open Space
1	Other Hays
1	Alfalfa
1	Spring Wheat

49b Forested Lake Plains

%	**Class**
53	Woody Wetlands
25	Deciduous Forest
7	Herbaceous Wetlands
5	Mixed Forest
2	Shrubland
2	Developed/Open Space
1	Evergreen Forest
1	Open Water
1	Alfalfa

50a Lake Superior Lacustrine Clay Plain

%	Class
50	Deciduous Forest
18	Woody Wetlands
11	Evergreen Forest
6	Shrubland
4	Developed/Open Space
3	Herbaceous Wetlands
3	Other Hays
2	Developed/Low Intensity
2	Open Water
1	Mixed Forest
1	Developed/Medium Intensity

50b Minnesota/Wisconsin Upland Till Plain

%	Class
41	Deciduous Forest
23	Woody Wetlands
14	Herbaceous Wetlands
8	Open Water
4	Other Hays
3	Developed/Open Space
1	Grassland/Pasture
1	Shrubland
1	Evergreen Forest
1	Alfalfa
1	Soybeans
1	Corn

50m Mesabi Range

%	Class
31	Deciduous Forest
17	Woody Wetlands
12	Barren
10	Mixed Forest
8	Shrubland
8	Open Water
4	Developed/Open Space
3	Evergreen Forest
2	Herbaceous Wetlands
2	Developed/Low Intensity
1	Grassland/Pasture
1	Developed/Medium Intensity

50n Boundary Lakes and Hills

%	Class
26	Woody Wetlands
21	Mixed Forest
17	Evergreen Forest
16	Deciduous Forest
15	Open Water
3	Shrubland
1	Herbaceous Wetlands
1	Developed/Open Space

50o Glacial Lakes Upham and Aitken

%	Class
52	Woody Wetlands
20	Deciduous Forest
9	Herbaceous Wetlands
5	Mixed Forest
3	Shrubland
2	Evergreen Forest
2	Developed/Open Space
2	Open Water
2	Other Hays

50p Toimi Drumlins

%	Class
46	Woody Wetlands
20	Deciduous Forest
11	Mixed Forest
9	Evergreen Forest
5	Shrubland
4	Open Water
2	Herbaceous Wetlands
2	Developed/Open Space

50q Itasca and St. Louis Moraines

%	Class
56	Deciduous Forest
11	Open Water
10	Woody Wetlands
6	Herbaceous Wetlands
4	Evergreen Forest
2	Grassland/Pasture
2	Shrubland
2	Developed/Open Space
2	Other Hays
1	Alfalfa
1	Corn

50r Chippewa Plains

%	Class
41	Deciduous Forest
19	Woody Wetlands
13	Open Water
9	Herbaceous Wetlands
7	Evergreen Forest
2	Grassland/Pasture
2	Developed/Open Space
2	Alfalfa
1	Shrubland
1	Mixed Forest
1	Other Hays

50s Nashwauk/Marcell Moraines and Uplands

%	Class
32	Woody Wetlands
29	Deciduous Forest
13	Mixed Forest
9	Open Water
6	Evergreen Forest
4	Shrubland
3	Herbaceous Wetlands
3	Developed/Open Space

50t North Shore Highlands

%	Class
40	Deciduous Forest
17	Evergreen Forest
16	Mixed Forest
14	Woody Wetlands
5	Shrubland
4	Developed/Open Space
2	Open Water
1	Developed/Low Intensity

51a St. Croix Outwash Plain

%	Class
22	Developed/Low Intensity
17	Deciduous Forest
13	Developed/Medium Intensity
11	Developed/Open Space
10	Grassland/Pasture
7	Developed/High Intensity
7	Open Water
6	Herbaceous Wetlands
2	Corn
1	Evergreen Forest
1	Other Hays
1	Alfalfa
1	Soybeans

51h Anoka Sand Plain and Mississippi Valley Outwash

%	Class
23	Herbaceous Wetlands
23	Deciduous Forest
13	Corn
7	Developed/Open Space
6	Developed/Low Intensity
6	Soybeans
5	Grassland/Pasture
4	Open Water
3	Developed/Medium Intensity
2	Other Hays
2	Alfalfa
1	Woody Wetlands
1	Evergreen Forest
1	Developed/High Intensity
1	Potatoes

51i Big Woods

%	Class
22	Corn
17	Soybeans
14	Deciduous Forest
13	Herbaceous Wetlands
7	Grassland/Pasture
7	Open Water
6	Developed/Open Space
5	Developed/Low Intensity
2	Shrubland
2	Developed/Medium Intensity
2	Other Hays
2	Alfalfa
1	Developed/High Intensity

51j Alexandria Moraines and Detroit Lakes Outwash Plain

%	Class
23	Deciduous Forest
14	Corn
13	Open Water
13	Soybeans
11	Grassland/Pasture
10	Herbaceous Wetlands
4	Developed/Open Space
4	Alfalfa
2	Spring Wheat
1	Evergreen Forest
1	Developed/Low Intensity
1	Other Hays

51k McGrath Till Plain and Drumlins

%	Class
22	Corn
19	Deciduous Forest
18	Herbaceous Wetlands
9	Soybeans
7	Grassland/Pasture
7	Alfalfa
5	Developed/Open Space
5	Other Hays
3	Open Water
2	Woody Wetlands
1	Shrubland
1	Developed/Low Intensity

51l Wadena/Todd Drumlins and Osakis Till Plain

%	Class
23	Deciduous Forest
17	Corn
16	Herbaceous Wetlands
8	Grassland/Pasture
8	Soybeans
6	Alfalfa
5	Other Hays
4	Developed/Open Space
3	Evergreen Forest
2	Woody Wetlands
2	Shrubland
2	Open Water
1	Potatoes
1	Dry Beans
1	Oats
1	Spring Wheat

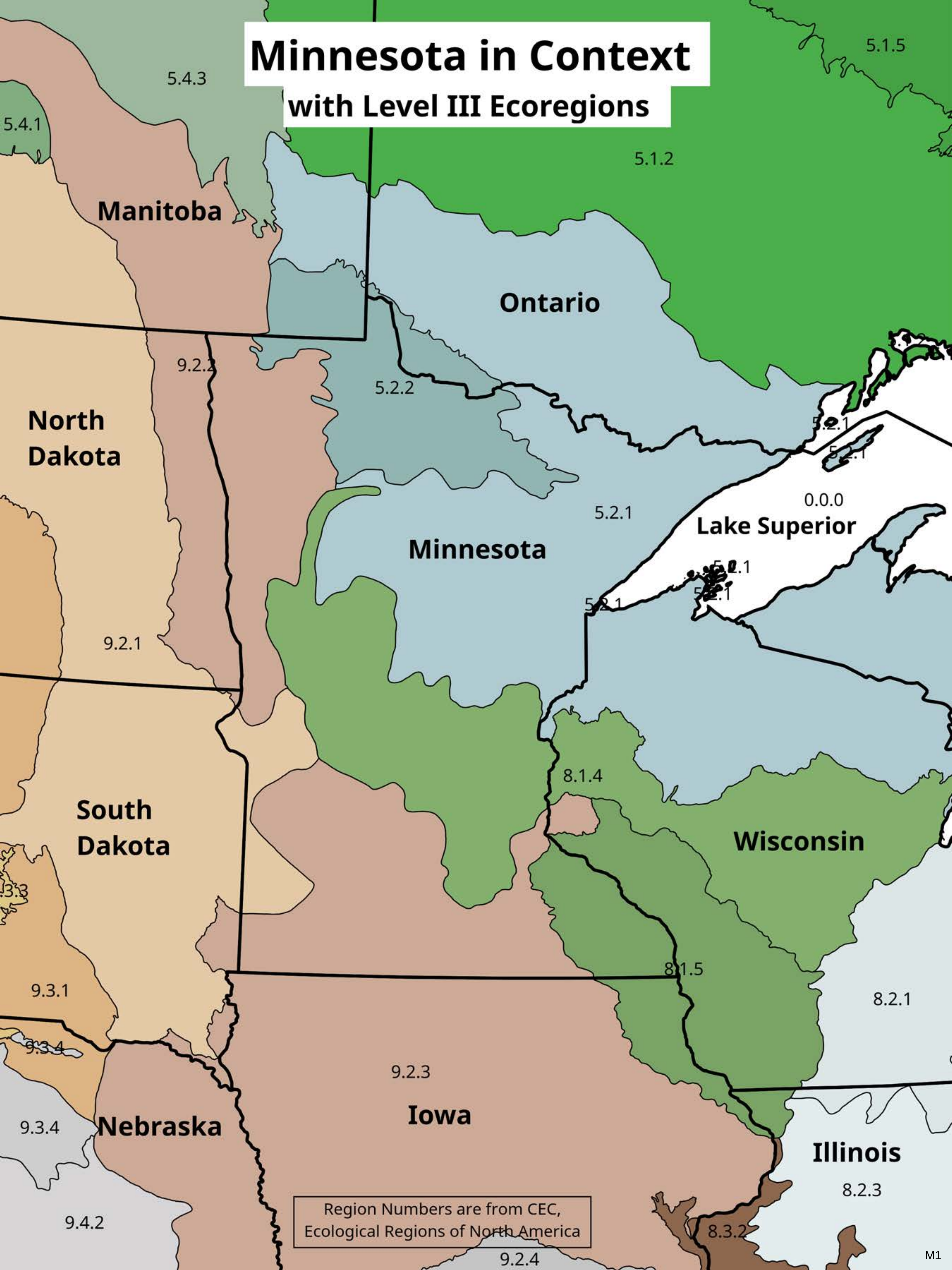
52b Blufflands and Coulees

%	Class
40	Deciduous Forest
24	Grassland/Pasture
14	Corn
6	Soybeans
4	Developed/Open Space
3	Open Water
3	Alfalfa
2	Woody Wetlands
1	Herbaceous Wetlands
1	Developed/Low Intensity

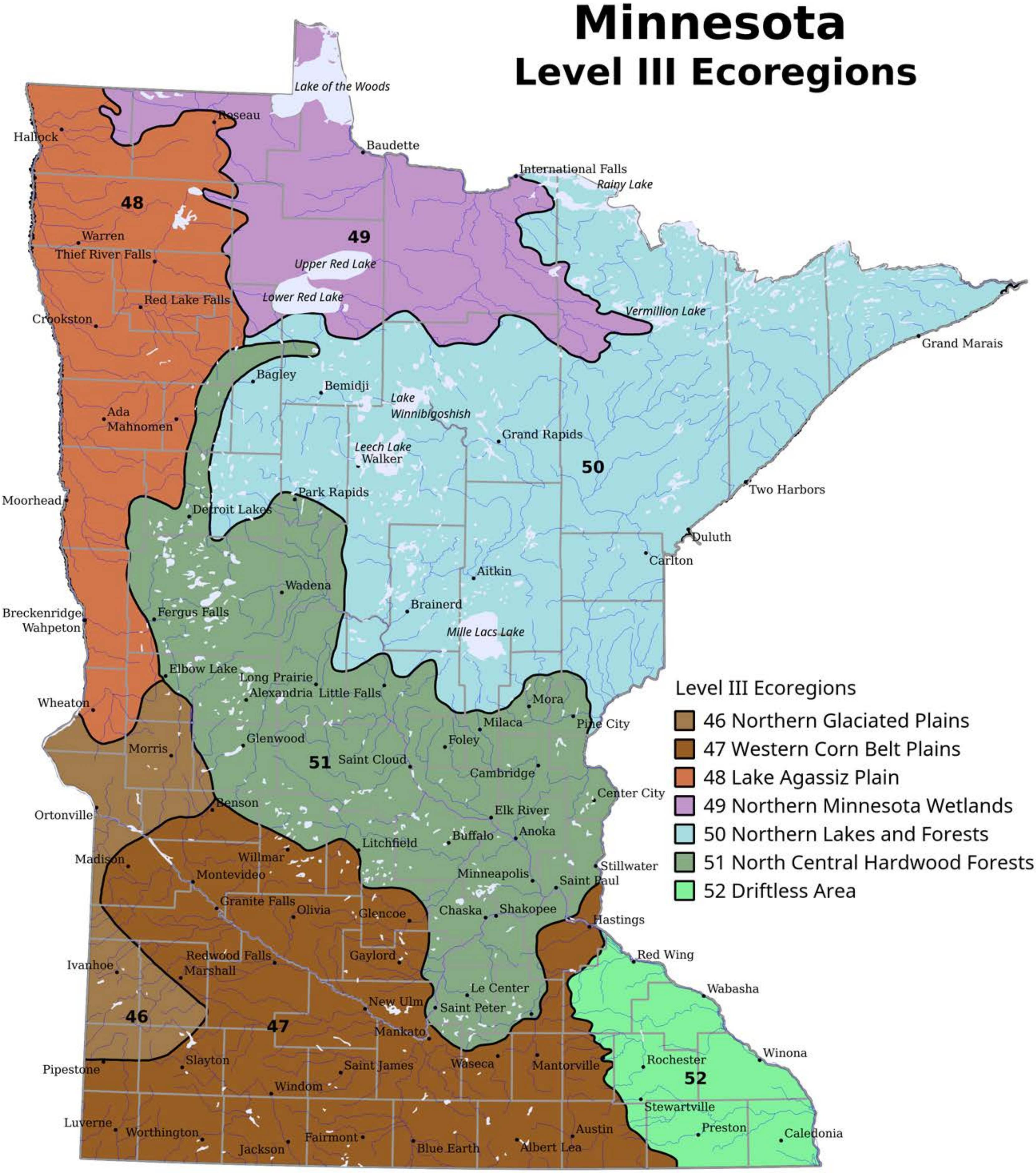
52c Rochester/Paleozoic Plateau Upland

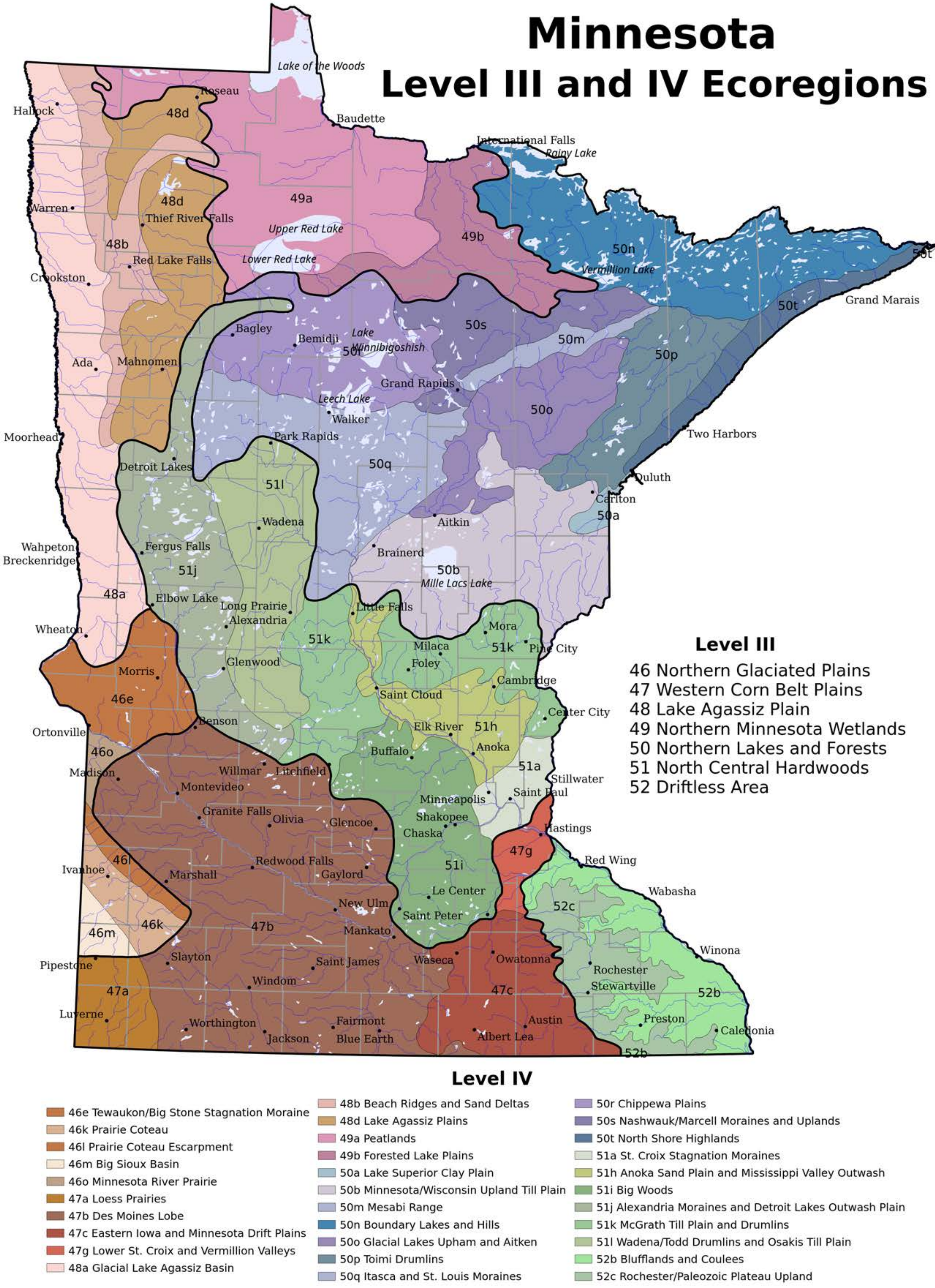
%	Class
32	Grassland/Pasture
28	Corn
17	Soybeans
9	Deciduous Forest
5	Developed/Open Space
4	Alfalfa
2	Developed/Low Intensity
1	Developed/Medium Intensity
1	Peas
1	Sweet Corn

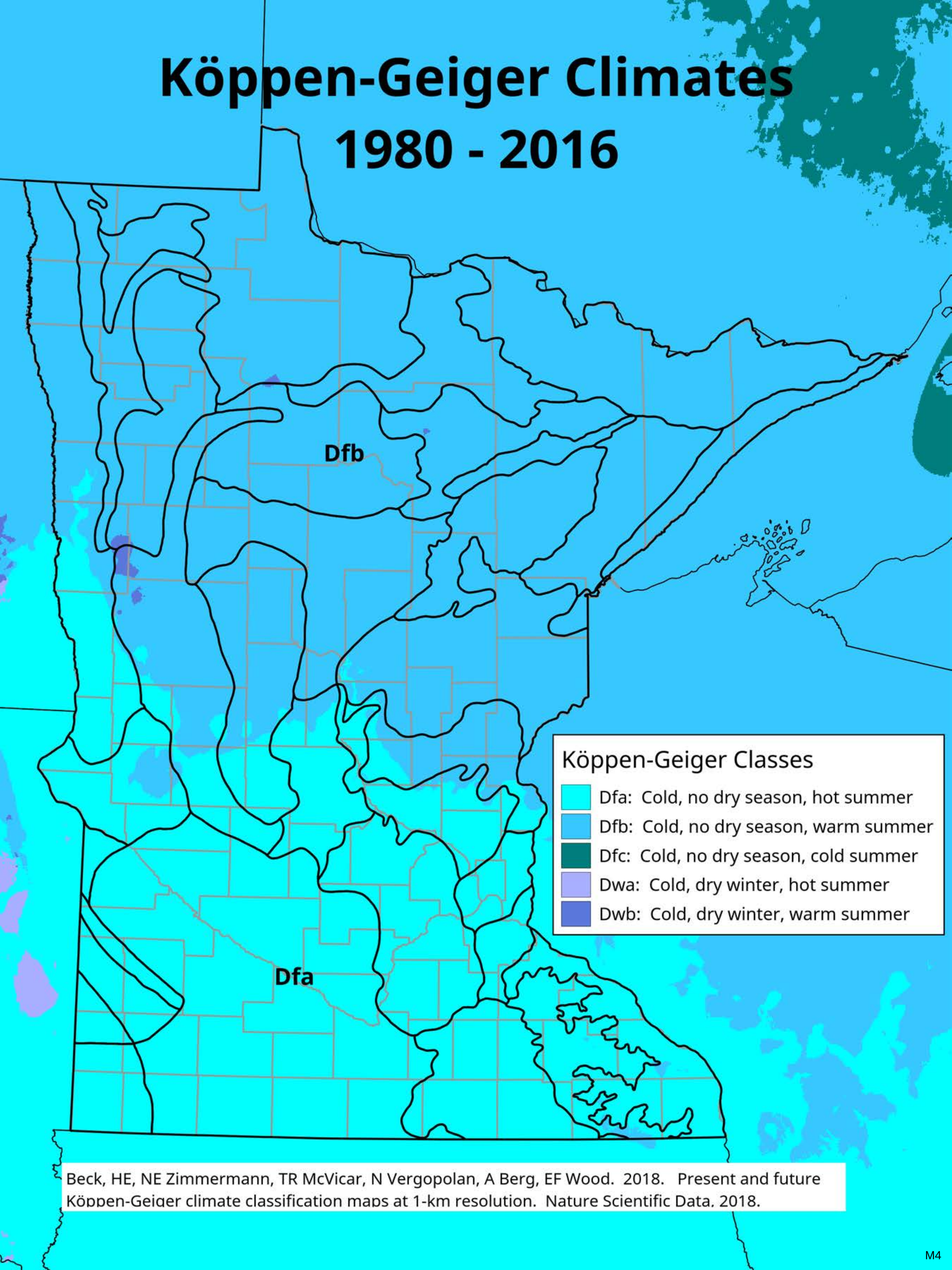
Minnesota in Context
with Level III Ecoregions



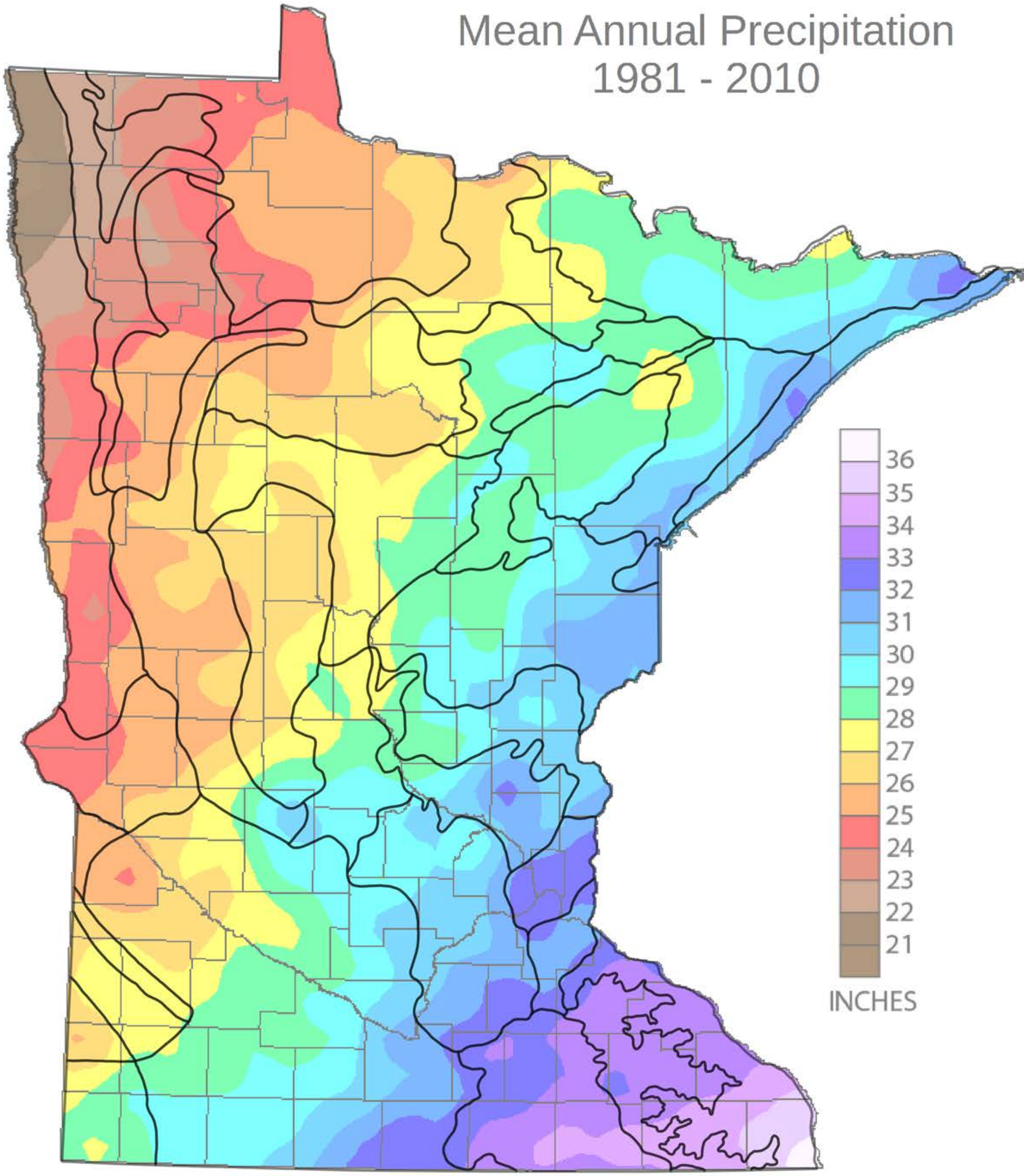
Minnesota
Level III Ecoregions



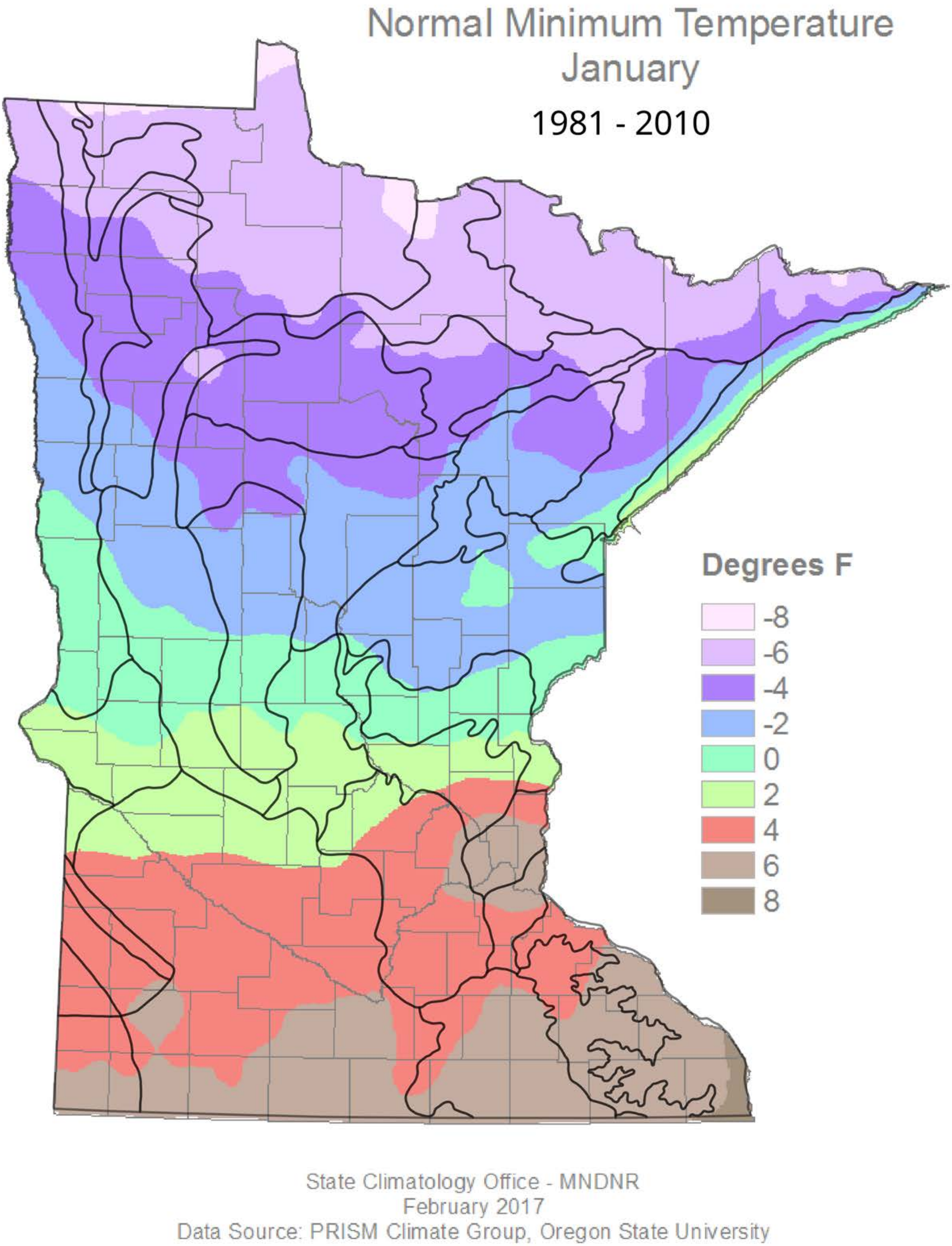

Minnesota
Level III and IV Ecoregions
Lake of the Woods
Roseau
Hallock
48d
Baudette
International Falls
Rainy Lake
Warren
48d
49a
Thief River Falls
Upper Red Lake
49b
50n
48b
Red Lake Falls
Lower Red Lake
Vermillion Lake
50t
Crookston
50t
Grand Marais
Bagley
Bemidji
Lake Winnibigoshish
50r
50s
50m
50p
Ada
Mahnomen
Grand Rapids
Leech Lake
Walker
50o
Moorhead
Park Rapids
Two Harbors
Detroit Lakes
50q
51l
Duluth
Carlton
50a
Wadena
Aitkin
Wahpeton
Breckenridge
Fergus Falls
Brainerd
51j
50b
Mille Lacs Lake
48a
Elbow Lake
Long Prairie
Alexandria
Little Falls
Wheaton
Mora
51k
Milaca
51k
Pine City
Foley
Glenwood
Morris
Cambridge
46e
Saint Cloud
Center City
Benson
Elk River
51h
Ortonville
Anoka
46o
Buffalo
51a
Madison
Willmar
Litchfield
Stillwater
Montevideo
Saint Paul
Minneapolis
Granite Falls
Olivia
Glencoe
Shakopee
Chaska
Hastings
47g
46l
Redwood Falls
Red Wing
Ivanhoe
Marshall
Gaylord
51i
Wabasha
Le Center
52c
New Ulm
Saint Peter
46k
46m
47b
Mankato
Winona
Slayton
Waseca
Owatonna
Pipestone
Saint James
Rochester
Stewartville
Windom
47c
52b
47a
Luverne
Worthington
Fairmont
Austin
Preston
Caledonia
Jackson
Blue Earth
Albert Lea
52b
Level III
46 Northern Glaciated Plains
47 Western Corn Belt Plains
48 Lake Agassiz Plain
49 Northern Minnesota Wetlands
50 Northern Lakes and Forests
51 North Central Hardwoods
52 Driftless Area
Level IV
46e Tewaukon/Big Stone Stagnation Moraine
46k Prairie Coteau
46l Prairie Coteau Escarpment
46m Big Sioux Basin
46o Minnesota River Prairie
47a Loess Prairies
47b Des Moines Lobe
47c Eastern Iowa and Minnesota Drift Plains
47g Lower St. Croix and Vermillion Valleys
48a Glacial Lake Agassiz Basin
48b Beach Ridges and Sand Deltas
48d Lake Agassiz Plains
49a Peatlands
49b Forested Lake Plains
50a Lake Superior Clay Plain
50b Minnesota/Wisconsin Upland Till Plain
50m Mesabi Range
50n Boundary Lakes and Hills
50o Glacial Lakes Upham and Aitken
50p Toimi Drumlins
50q Itasca and St. Louis Moraines
50r Chippewa Plains
50s Nashwauk/Marcell Moraines and Uplands
50t North Shore Highlands
51a St. Croix Stagnation Moraines
51h Anoka Sand Plain and Mississippi Valley Outwash
51i Big Woods
51j Alexandria Moraines and Detroit Lakes Outwash Plain
51k McGrath Till Plain and Drumlins
51l Wadena/Todd Drumlins and Osakis Till Plain
52b Blufflands and Coulees
52c Rochester/Paleozoic Plateau Upland


Köppen-Geiger Climates
1980 - 2016
Dfb
Dfa
Köppen-Geiger Classes
Dfa: Cold, no dry season, hot summer
Dfb: Cold, no dry season, warm summer
Dfc: Cold, no dry season, cold summer
Dwa: Cold, dry winter, hot summer
Dwb: Cold, dry winter, warm summer
Beck, HE, NE Zimmermann, TR McVicar, N Vergopolan, A Berg, EF Wood. 2018. Present and future Köppen-Geiger climate classification maps at 1-km resolution. Nature Scientific Data, 2018.
M4

Mean Annual Precipitation
1981 - 2010

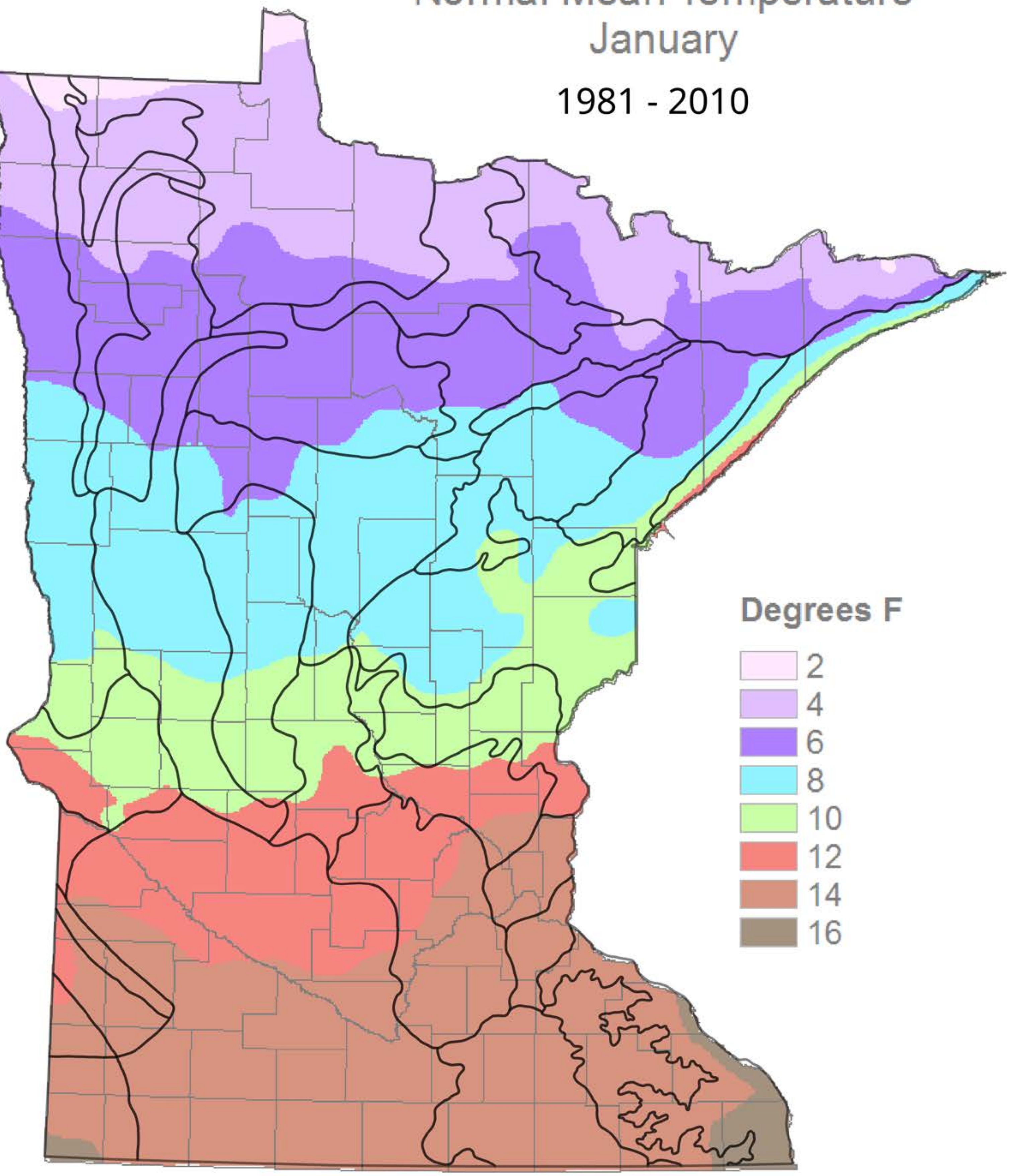


State Climatology Office
DNR Division of Ecological and Water Resources
August 2012

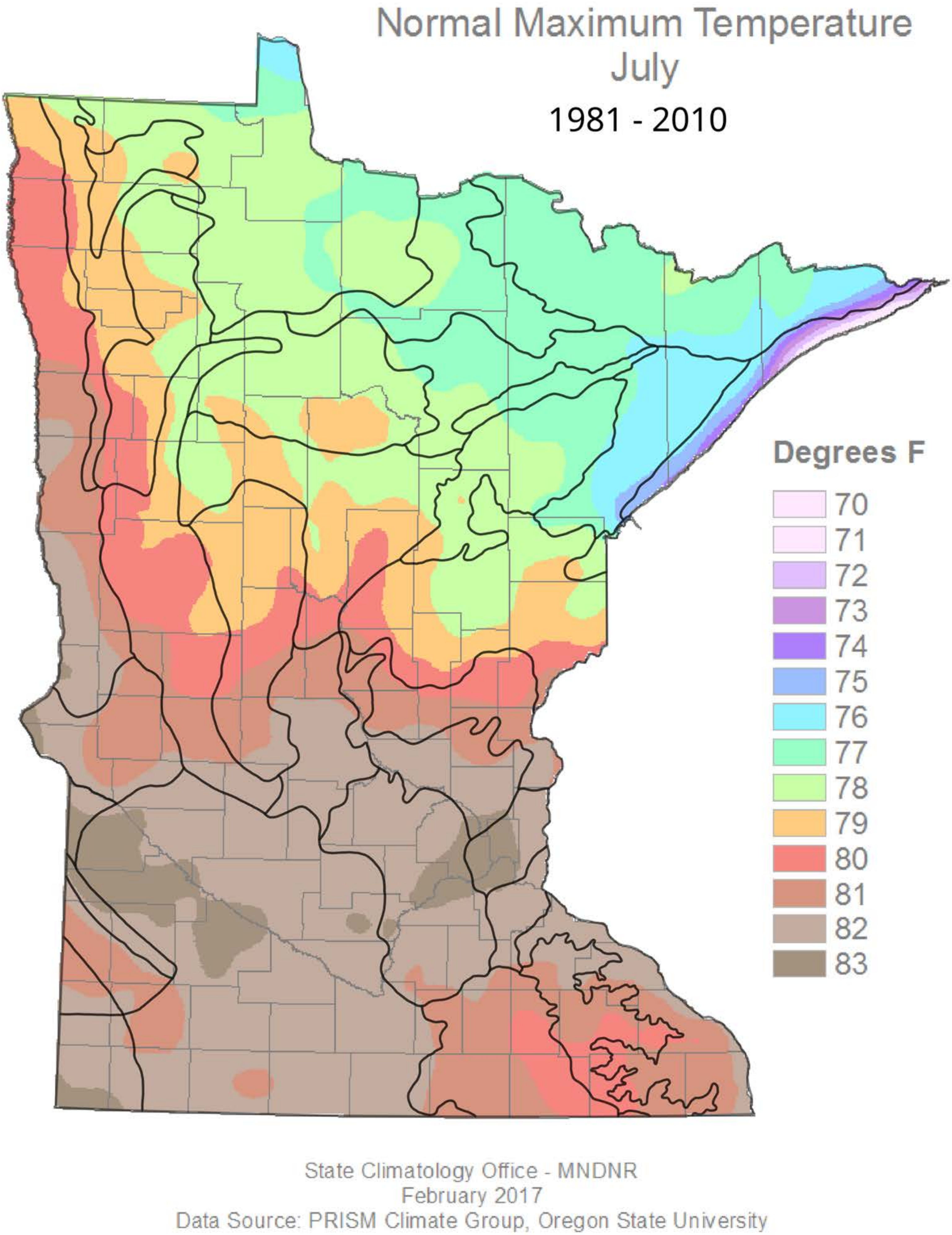

Normal Minimum Temperature
January
1981 - 2010
Degrees F
-8
-6
-4
-2
0
2
4
6
8
State Climatology Office - MNDNR
February 2017
Data Source: PRISM Climate Group, Oregon State University

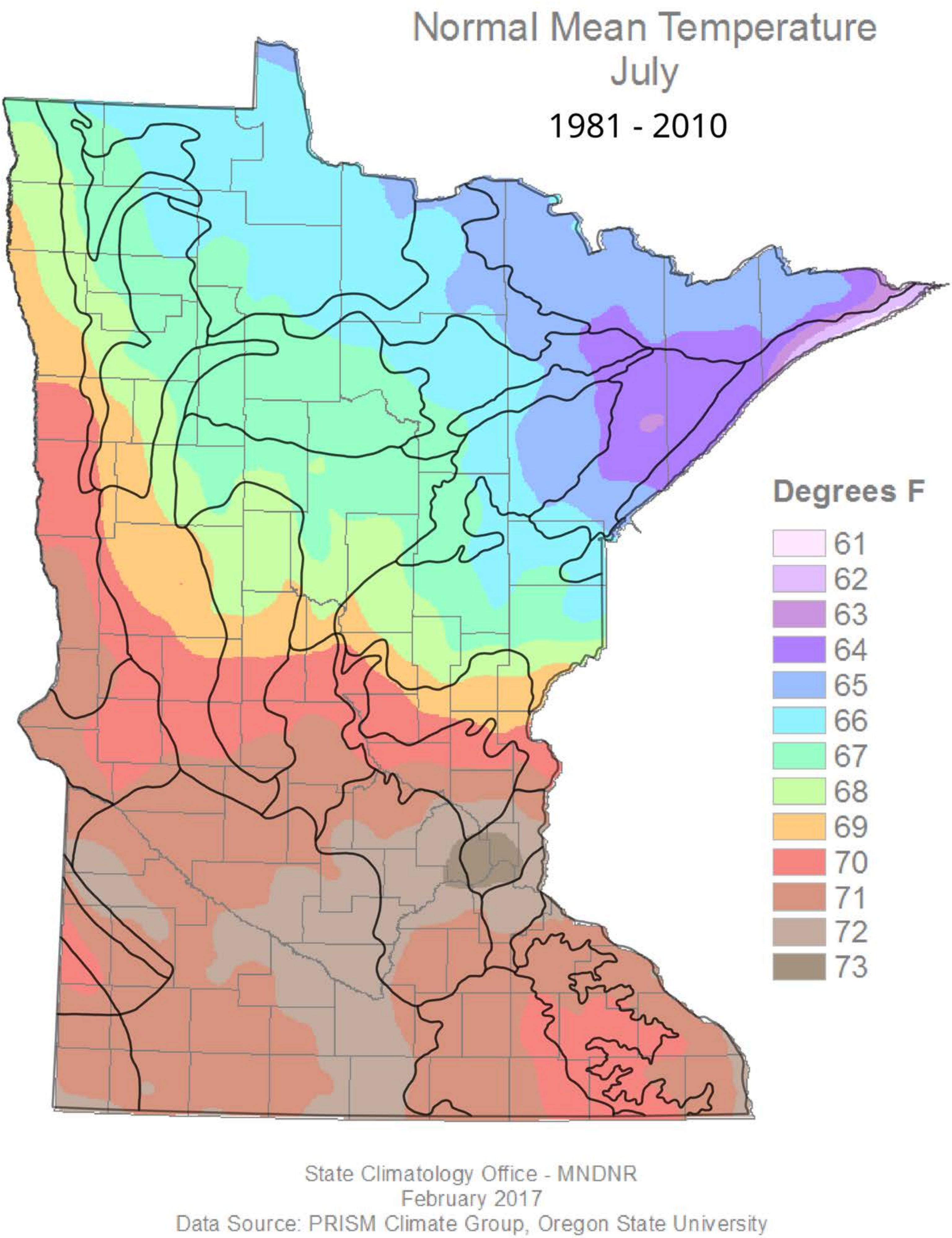
Normal Mean Temperature January

1981 - 2010

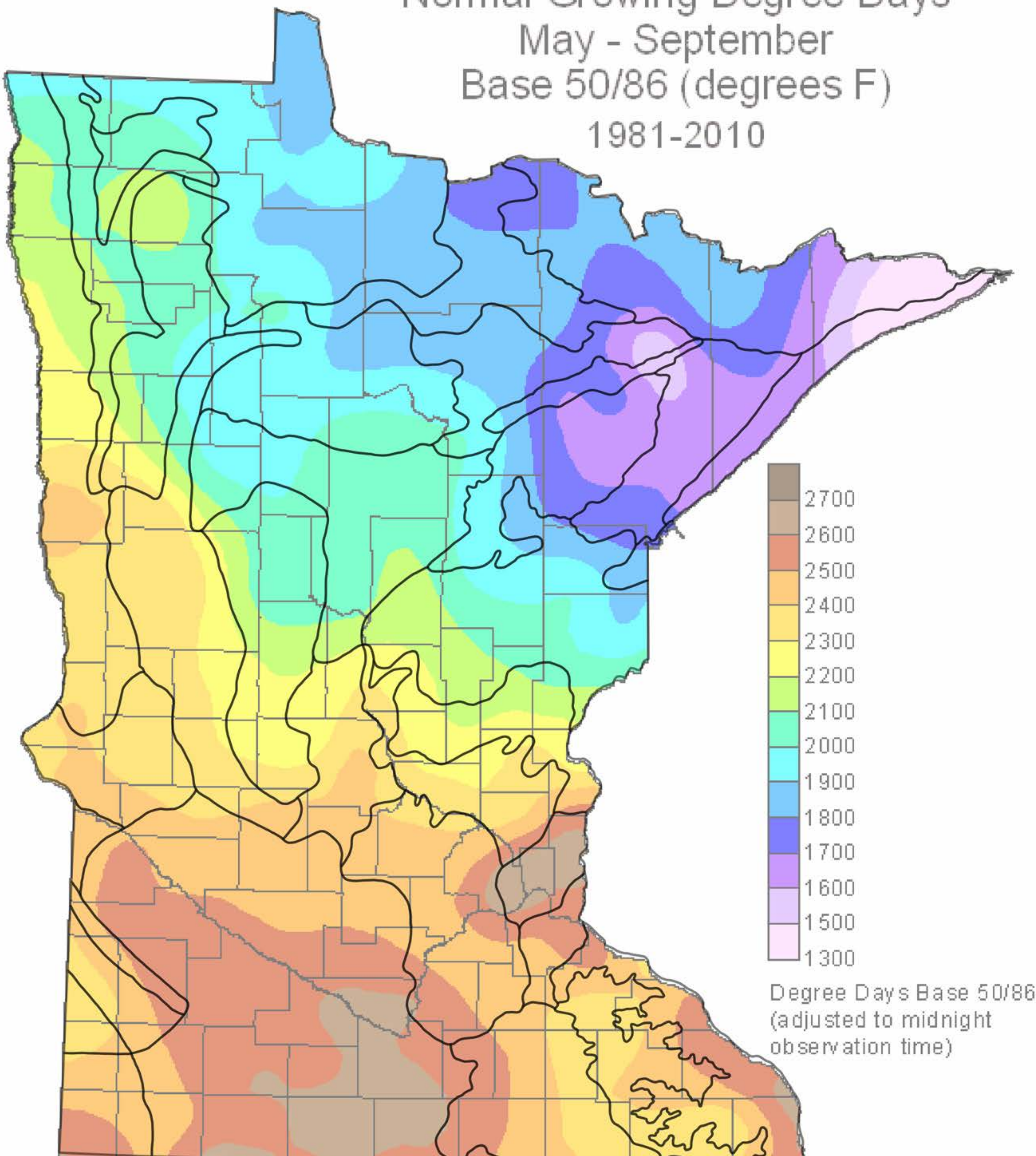


State Climatology Office - MNDNR
February 2017
Data Source: PRISM Climate Group, Oregon State University


Normal Maximum Temperature
July
1981 - 2010
Degrees F
70
71
72
73
74
75
76
77
78
79
80
81
82
83
State Climatology Office - MNDNR
February 2017
Data Source: PRISM Climate Group, Oregon State University

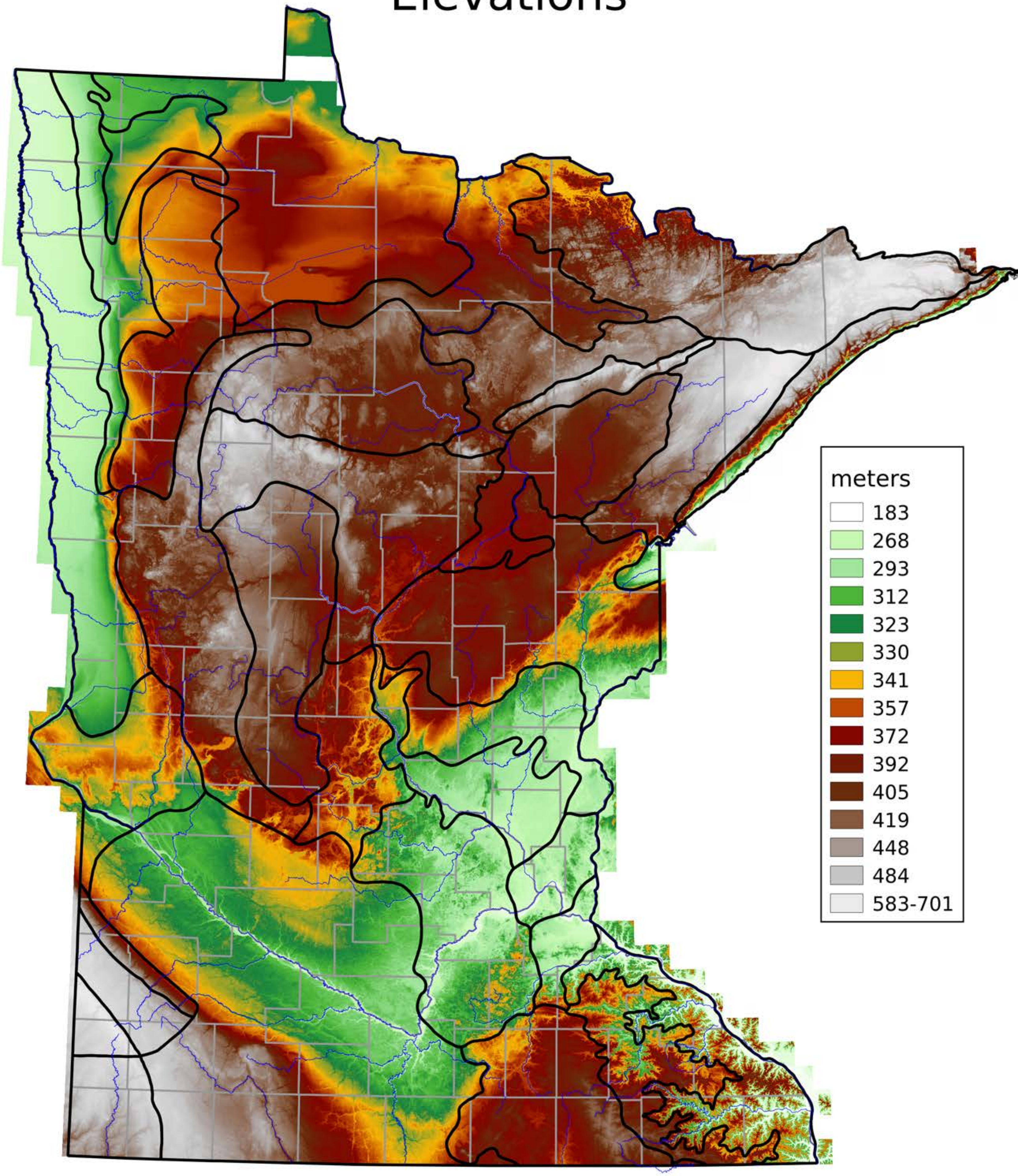

Normal Mean Temperature
July
1981 - 2010
Degrees F
61
62
63
64
65
66
67
68
69
70
71
72
73
State Climatology Office - MNDNR
February 2017
Data Source: PRISM Climate Group, Oregon State University

Normal Growing Degree Days
May - September
Base 50/86 (degrees F)
1981-2010



State Climatology Office - MNDNR

Elevations



Quantile Classification, 15 classes. Lowest elevation 183 meters at Lake Superior, highest elevation 701 meters at Eagle Mountain about 25 km from Lake Superior northwest of Grand Marais.

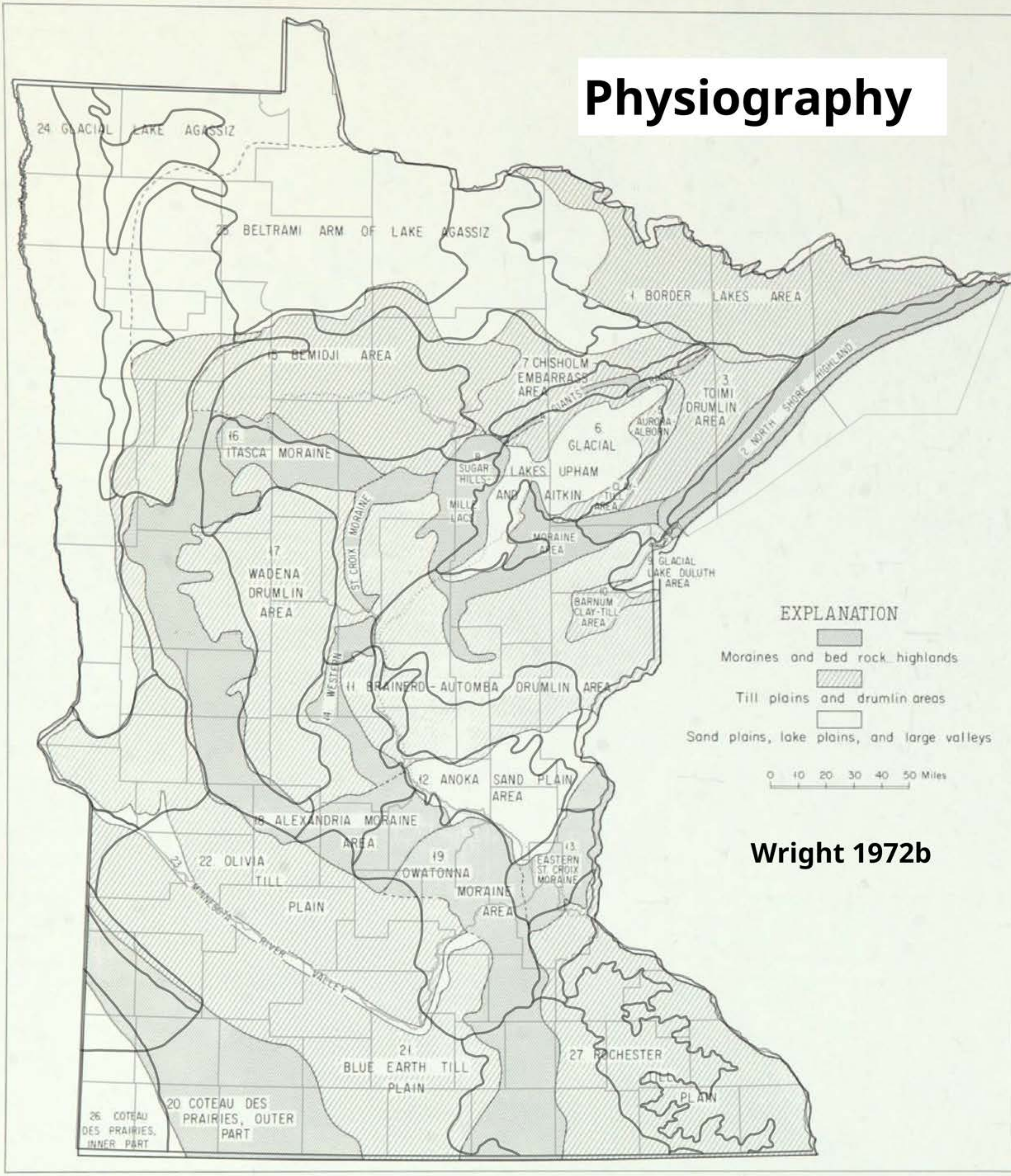
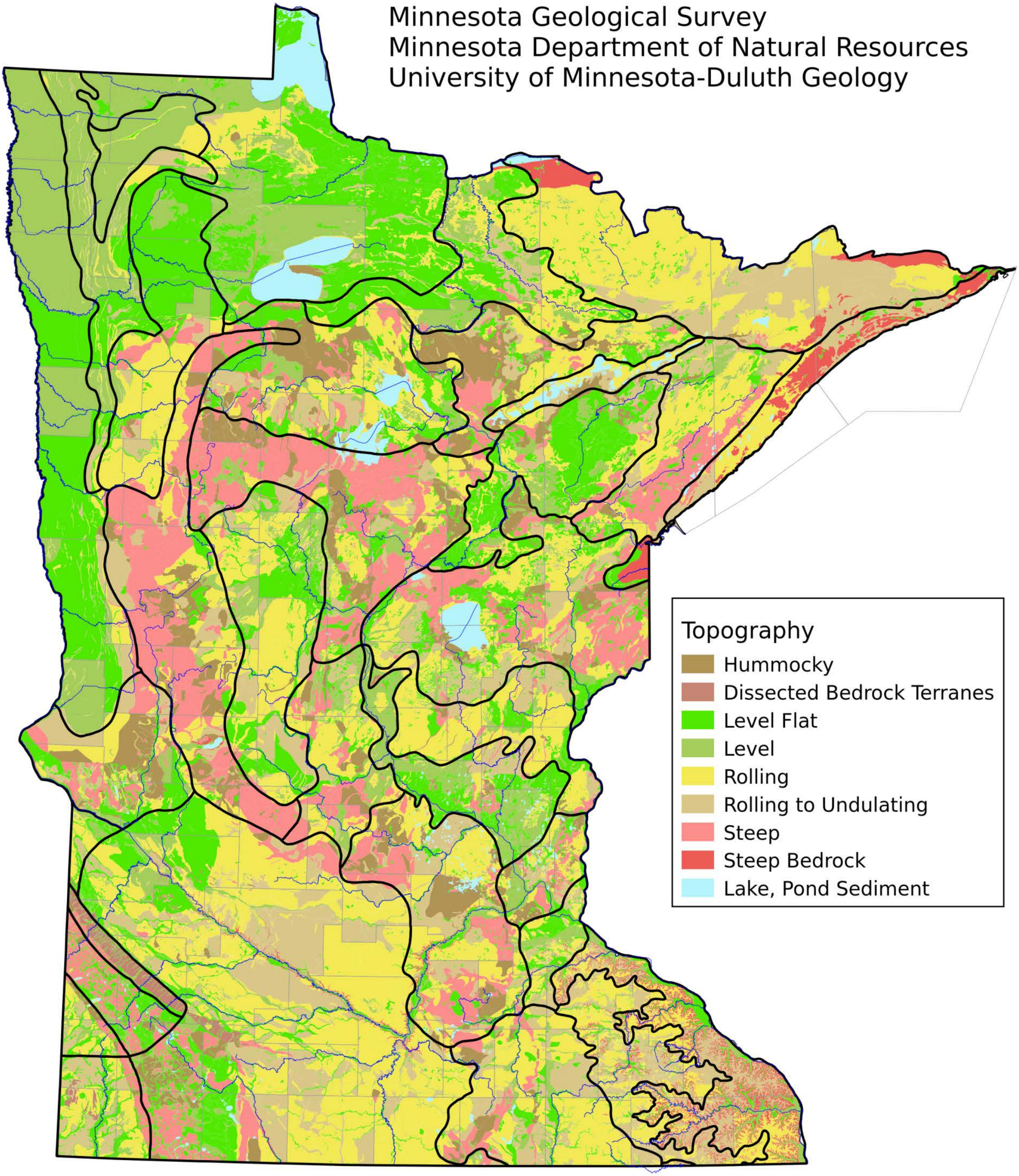


Figure VII-28. Map of physiographic areas in Minnesota. 1, border lakes area; 2, North Shore Highland; 3, Toimi drumlin area; 4, Giants range; 5, Aurora-Alborn clay-till area; 6, Glacial Lakes Upham and Aitkin; 7, Chisholm-Embarrass area; 8, Sugar Hills-Mille Lacs area; 9, Glacial Lake Duluth area; 10, Barnum clay-till area; 11, Brainerd-Automba drumlin area; 12, Anoka sandplain area; 13, eastern St. Croix moraine; 14, western St. Croix moraine; 15, Bemidji area; 16, Itasca moraine; 17, Wadena drumlin area; 18, Alexandria moraine area; 19, Owatonna moraine area; 20, Coteau des Prairies, outer part; 21, Blue Earth till plain; 22, Olivia till plain; 23, Minnesota River Valley; 24, Glacial Lake Agassiz; 25, Beltrami arm of Lake Agassiz; 26, Coteau des Prairies, inner part; 27, Rochester till plain.

Topography

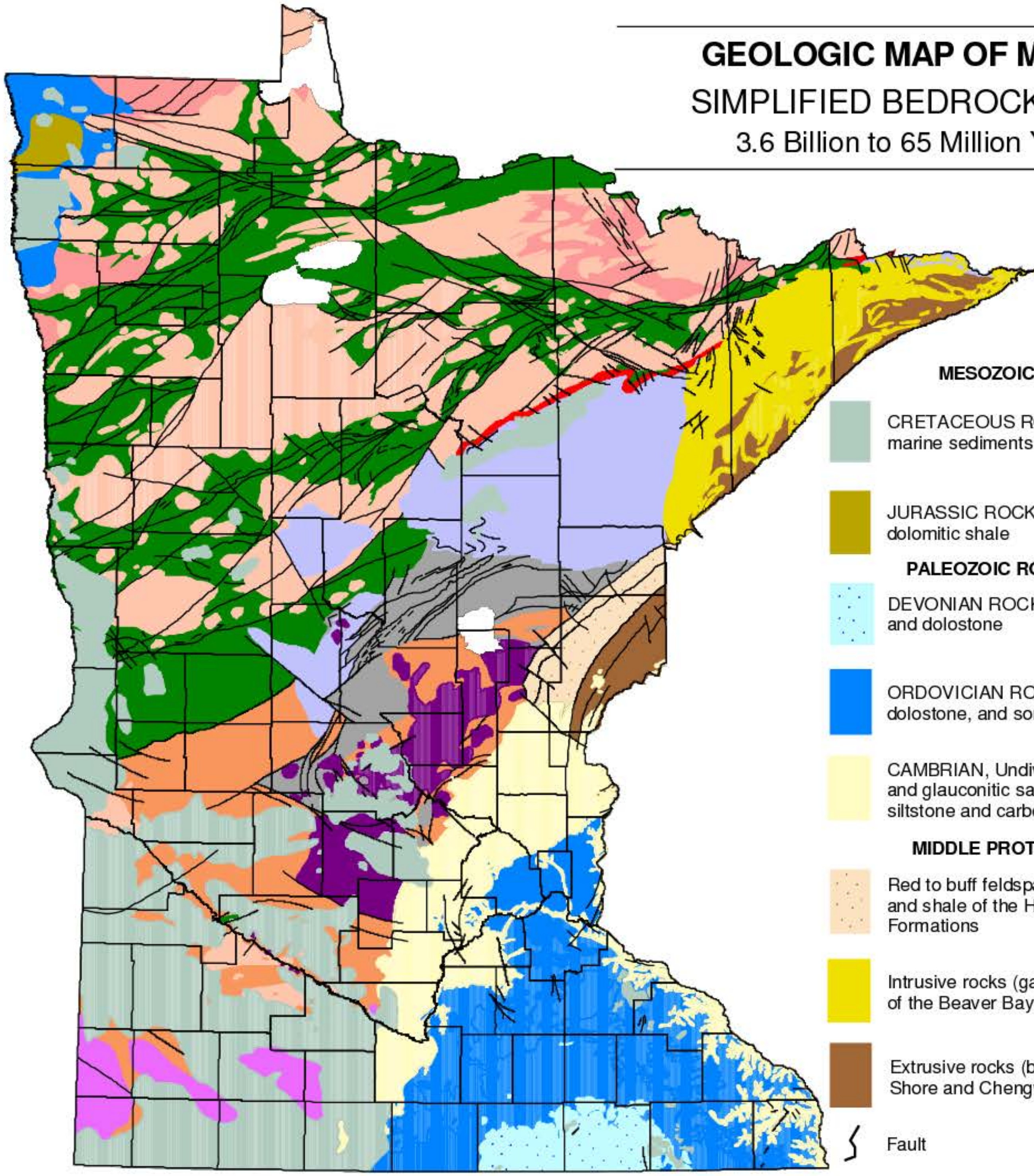
Minnesota Geological Survey
Minnesota Department of Natural Resources
University of Minnesota-Duluth Geology



GEOLOGIC MAP OF MINNESOTA

SIMPLIFIED BEDROCK GEOLOGY

3.6 Billion to 65 Million Years Ago



DESCRIPTION OF MAP UNITS

(mya = million years ago, bya = billion years ago)

MESOZOIC ROCKS (225 to 65 mya)

- CRETACEOUS ROCKS, Undivided - Dominantly marine sediments; shale and sandstone
- JURASSIC ROCKS, Undivided - Reddish brown dolomitic shale

PALEOZOIC ROCKS (600 to 225 mya)

- DEVONIAN ROCKS, Undivided - Limestone and dolostone
- ORDOVICIAN ROCKS, Undivided - Limestone, dolostone, and some sandstone and shale
- CAMBRIAN, Undivided - Quartzose and glauconitic sandstone; lesser amounts of siltstone and carbonate

MIDDLE PROTEROZOIC (1.6 to 0.9 bya)

- Red to buff feldspathic to quartzose sandstone and shale of the Hinckley and Fond du Lac Formations
- Intrusive rocks (gabbro, granite and anorthosite) of the Beaver Bay and Duluth Complexes
- Extrusive rocks (basalt and rhyolite) of the North Shore and Chengwatana Volcanic Groups
- Fault

EARLY PROTEROZOIC ROCKS (2.5 to 1.6 bya)

- Sedimentary and Metamorphic rocks of the Sioux Quartzite formation
- Intrusive rocks (granite and granodiorite) of the Penokean orogeny
- Meta- and sedimentary rocks (argillite, slate, shale, graywacke) of the Virginia, Thomson and Rove Formations
- Iron-Formation (hematite and taconite) of the Biwabik and Gunflint Iron Formations
- Metasedimentary rocks (slate, quartzite and metagraywacke) intercalated with volcanic rocks and iron formations

LATE ARCHEAN ROCKS (3 to 2.5 bya)

- Intrusive rocks (granite, granodiorite and tonalite) of the Algoman Orogeny
- Meta-igneous rocks (granitic gneiss, schist and granite-rich migmatite) grading into granitic rock
- Meta-igneous extrusive rocks of mafic to felsic composition (greenstones/amphibolites) and metasedimentary rocks

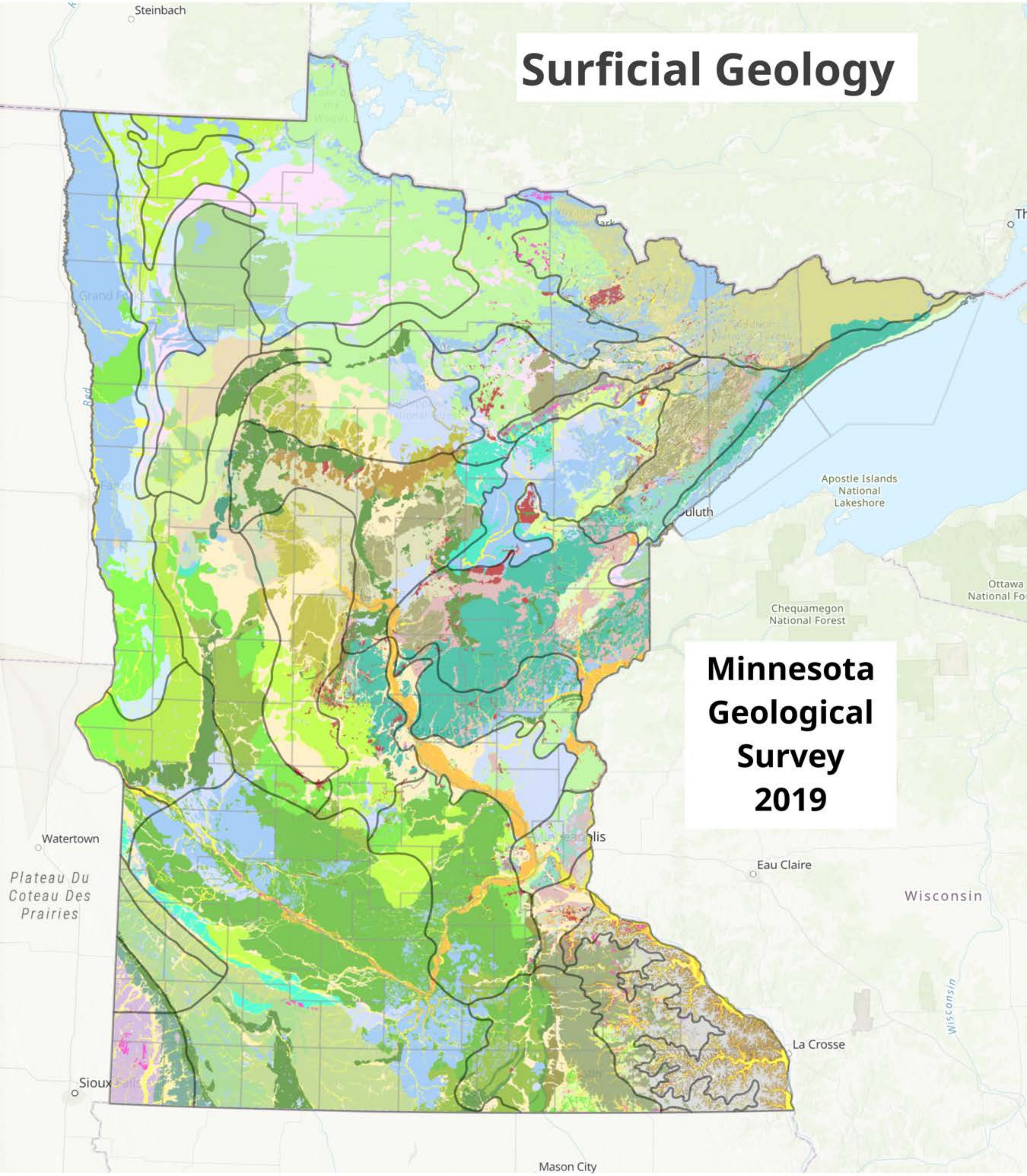
MIDDLE ARCHEAN ROCKS (3.6 to 3 bya)

- Quartzofeldspathic gneiss, amphibolite, and other high-grade metamorphic rocks

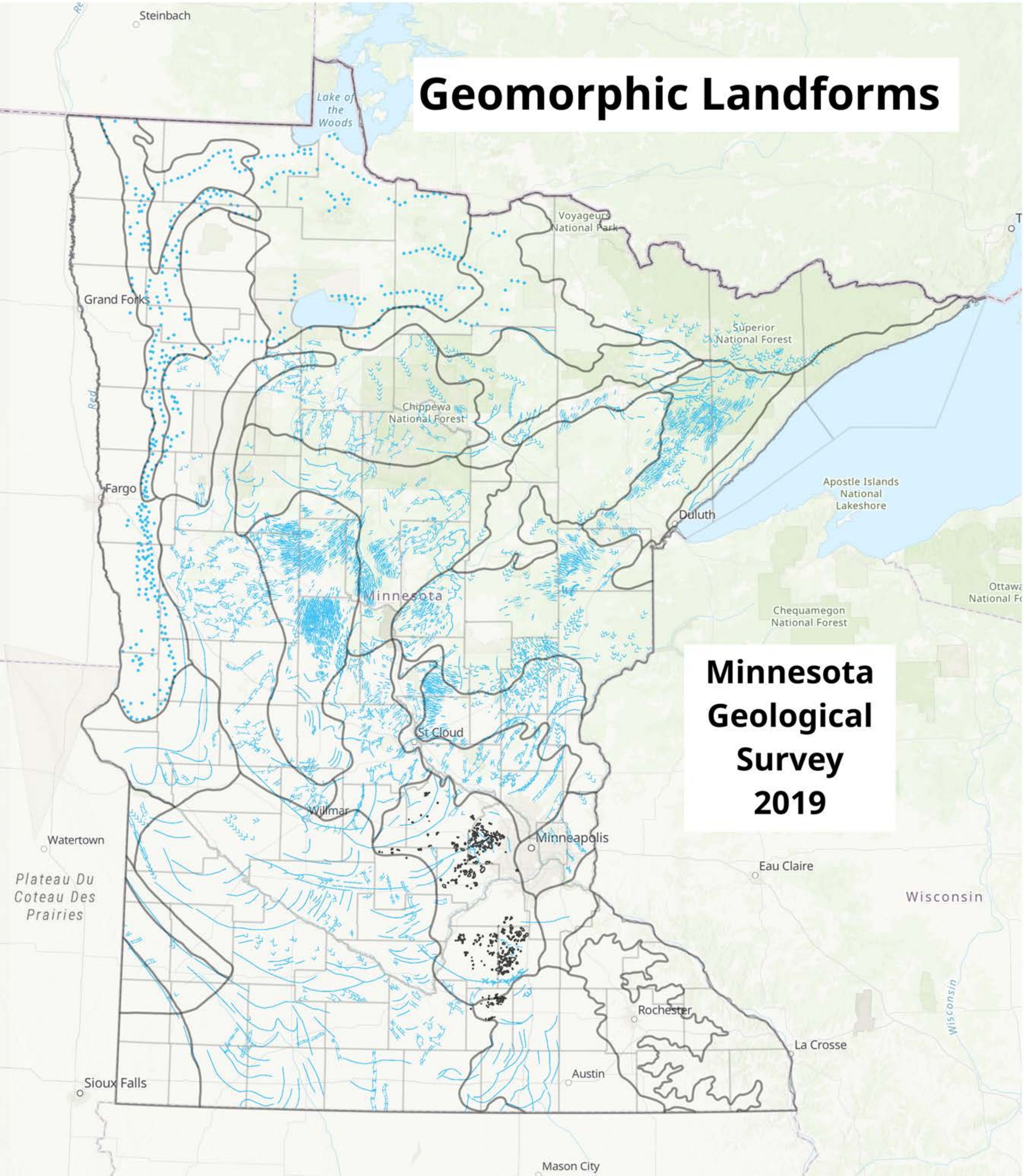
Bedrock map based on data from the University of Minnesota - Minnesota Geological Survey, *Bedrock Map of Minnesota, Bedrock Geology, 1993* - Compiled by G.B. Morey.

Simplified description by C.R. Howe, 2000, Mn/DOT

8/15/01



See legend following pages



See legend following pages

Surficial Geology Legend

- fil - Fill
- do - Overburden dump mound
- drf - Other fill
- drc - Rock dump
- af - Alluvial fan
- al - Floodplain alluvium
- co - Colluvium
- tef - Terrace facies
- te - Terrace alluvium
- lo - Windblown sediment
- glc - Clayey sediment
- gls - Sandy sediment
- glg - Gravelly sediment
- glf - Sandy sediment
- fr - Forest River formation
- hu - Huot member
- rdo - Outwasy
- rdh - Stagnation-moraine sediment
- ru - Upper member
- rl - Lower member
- rlh - Stagnation-moraine sediment
- rlm - End-moraine sediment
- gro - Outwash
- grm - End-moraine sediment
- gs - St. Hilaire member
- gsh - Stagnation-moraine sediment
- gd - Dahlen member
- bwo - Outwash
- bwi - Ice-contact sediment
- bw - Boundary Waters formation
- bwh - Stagnation-moraine sediment
- bwm - End-moraine sediment
- bn - Nashwauk member
- bnh - Stagnation-moraine sediment
- aio - Outwash
- aii - Ice-contact sediment
- ap - Prairie Lake Member
- aph - Stagnation-moraine sediment
- an - Nelson Lake Member
- anh - Stagnation-moraine sediment
- aa - Alborn Member
- aah - Stagnation-moraine sediment
- aam - End-moraine sediment
- bdo - Outwash
- bdi - Ice-contact sediment
- bd - Blackduck Formation
- bdh - Stagnation-moraine sediment
- bdm - End-moraine sediment
- nuo - Outwash
- nui - Ice-contact sediment
- nu - New Ulm formation
- nh - Heiberg Member
- nhh - Stagnation-moraine sediment
- nhm - End-moraine sediment
- nl - Villard Member
- nlh - Stagnation-moraine sediment
- nlm - End-moraine sediment
- nt - Twin Cities Member
- nth - Stagnation-morain sediment
- ntm - End-moraine sediment
- nd - Dovray Member
- ni - Ivanhoe Member
- nih - Stagnation-moraine sediment
- nim - End-moraine sediment
- nm - Moland Member
- nv Verdi Member
- oro - Outwash
- on - New York Mills member

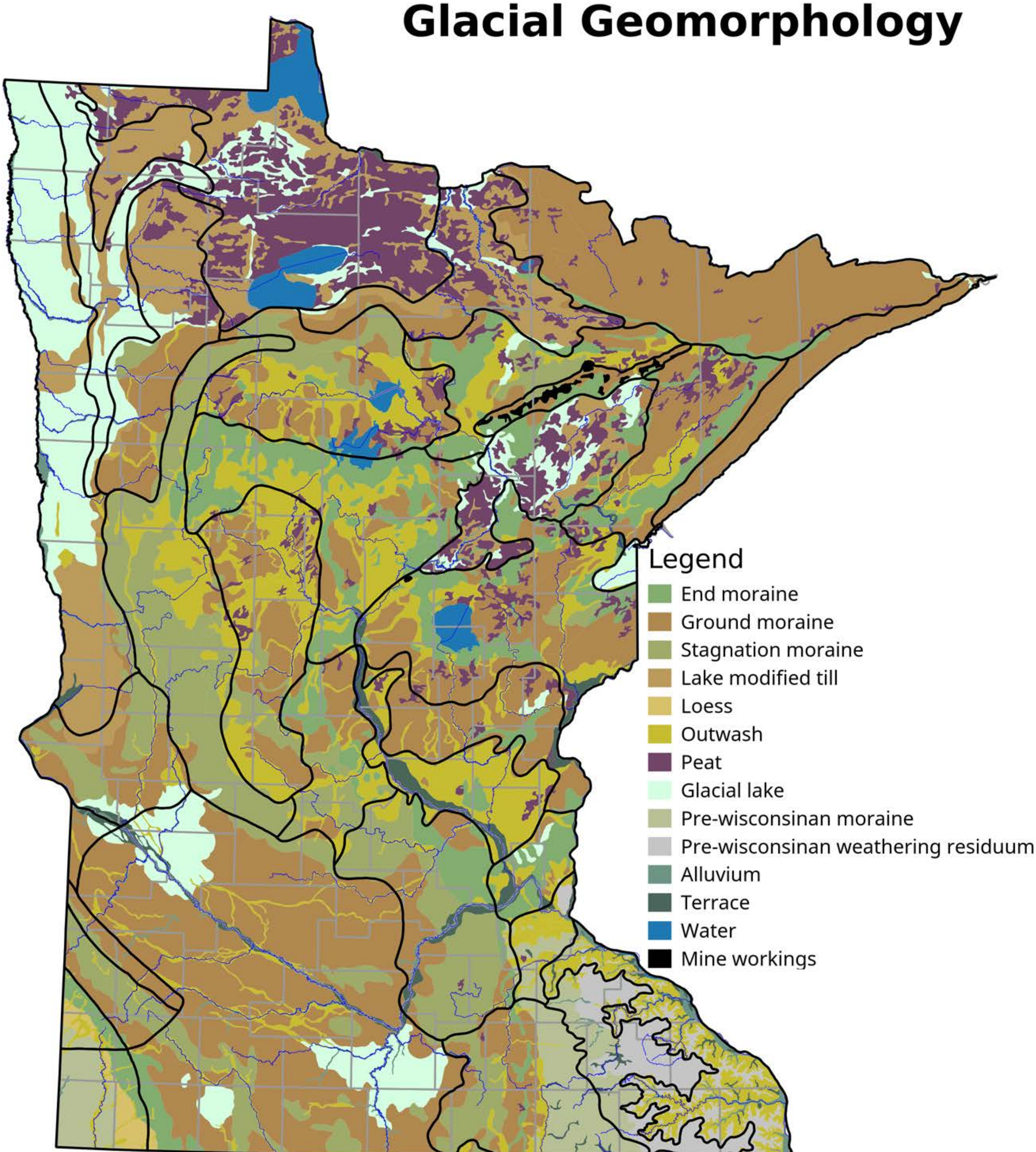
Surficial Geology Legend, continued

- onh - Stagnation-moraine sediment
- onm - End-moraine sediment
- bao - Outwash
- bai - Ice-contact sediment
- ba - Barnum Formation
- bam - End-moraine sediment
- bk - Knife River member (Marquette phase)
- bm - Moose Lake member (Nickerson phase
- bh - Mahtowa member (Split Rock phase)
- cro - Outwash
- cri - Ice-contact sediment
- cr - Cromwell Formation
- crh - Stagnation-moraine sediment
- crm - Mille Lacs Member
- cmm - End-moraine sediment
- ino - Outwash
- ini - Ice-contact sediment
- in - Independence Formation
- inh - Stanation-moraine sediment
- inm - End-moraine sediment
- is - South Long Lake Member
- heo - Outwash
- hei - Ice-contact sediment
- he - Hewitt Formation
- heh - Stagnation-moraine sediment
- hem - End-moraine sediment
- rfo - Outwash
- rfi - Ice-contact sediment
- bvo - Outwash
- bv - Browerville Formation
- rco - Outwash
- rc - Rose Creek/Saum Formation
- rb - Paleosol
- el - Elmdale Formation
- pio - Outwash
- pi - Pierce Formation
- ot - Old tills and sediment-covered bedrock
- uno - Outwash
- b - Bedrock
- sb - Thin sediment-covered bedrock

Geomorphic Landforms Legend

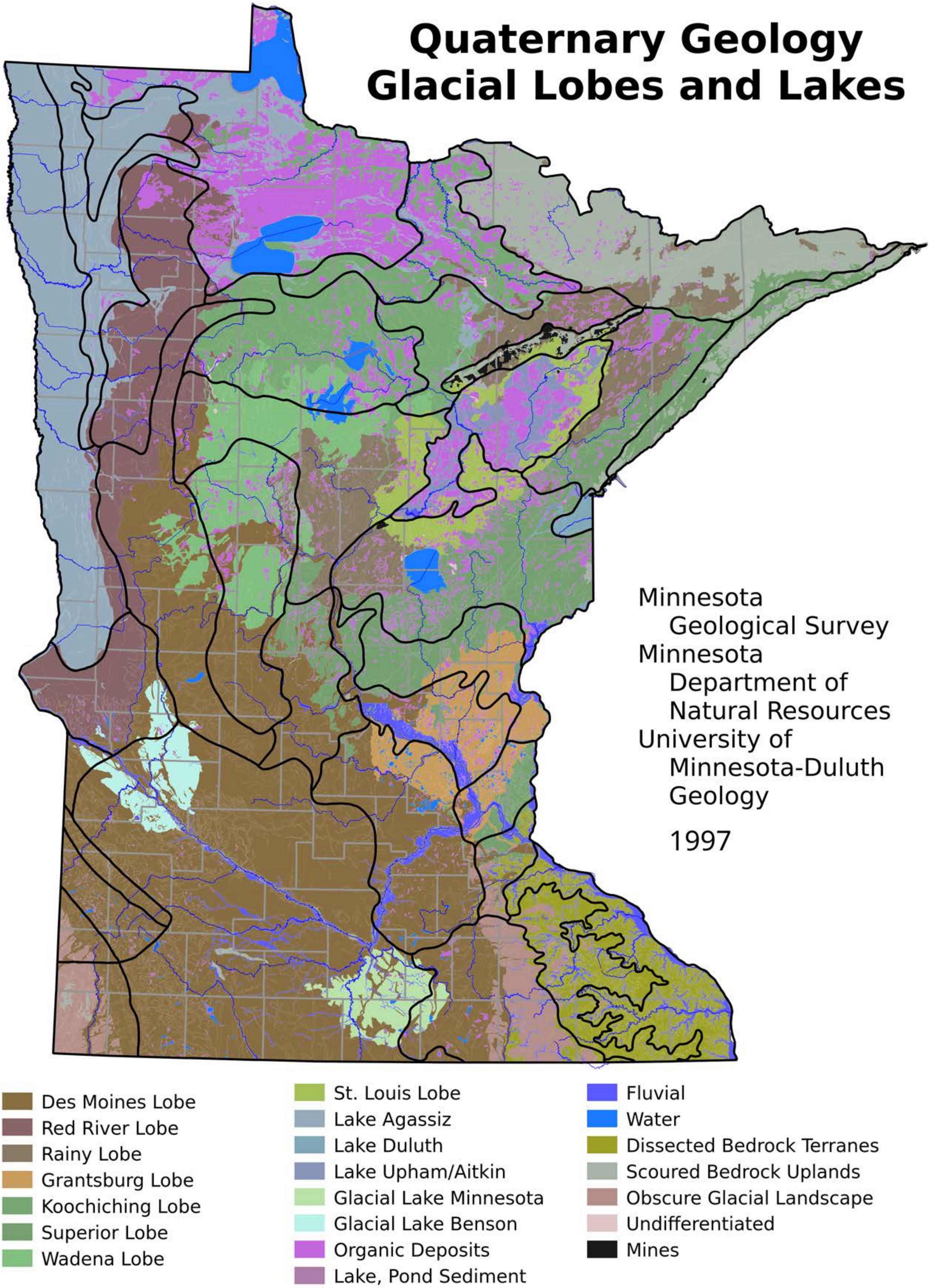
- 1.2.1 IWLP
- 13.18 Esker
- 13.45 Broad, irregular trough
- 12.1 Continuous scarp
- 13.1 Moraine
- 13.12 Sinuous ridge
- 13.14 Transverse ridge
- 13.2 Drift lineation
- 13.21 Drumlin
- 13.22 Crag and Tail
- 13.38 Linear feature
- 13.39 Alluvial fan
- 13.47 Discontinuous scarp
- 13.49 Ice margin
- 13.52 Ice margin, uncertain
- 13.58 Ice margin, up ice shown
- 13.59 Compaction ridge
- 13.72 Meltwater fan deposit
- 13.9 Meltwater flow direction
- 14.11 Circular depression
- 15.1 Shoreline

Quaternary Geology
Glacial Geomorphology



Minnesota Geological Survey, 1982

Quaternary Geology Glacial Lobes and Lakes



Minnesota Geological Survey
Minnesota Department of Natural Resources
University of Minnesota-Duluth Geology

1997

Glacial Features

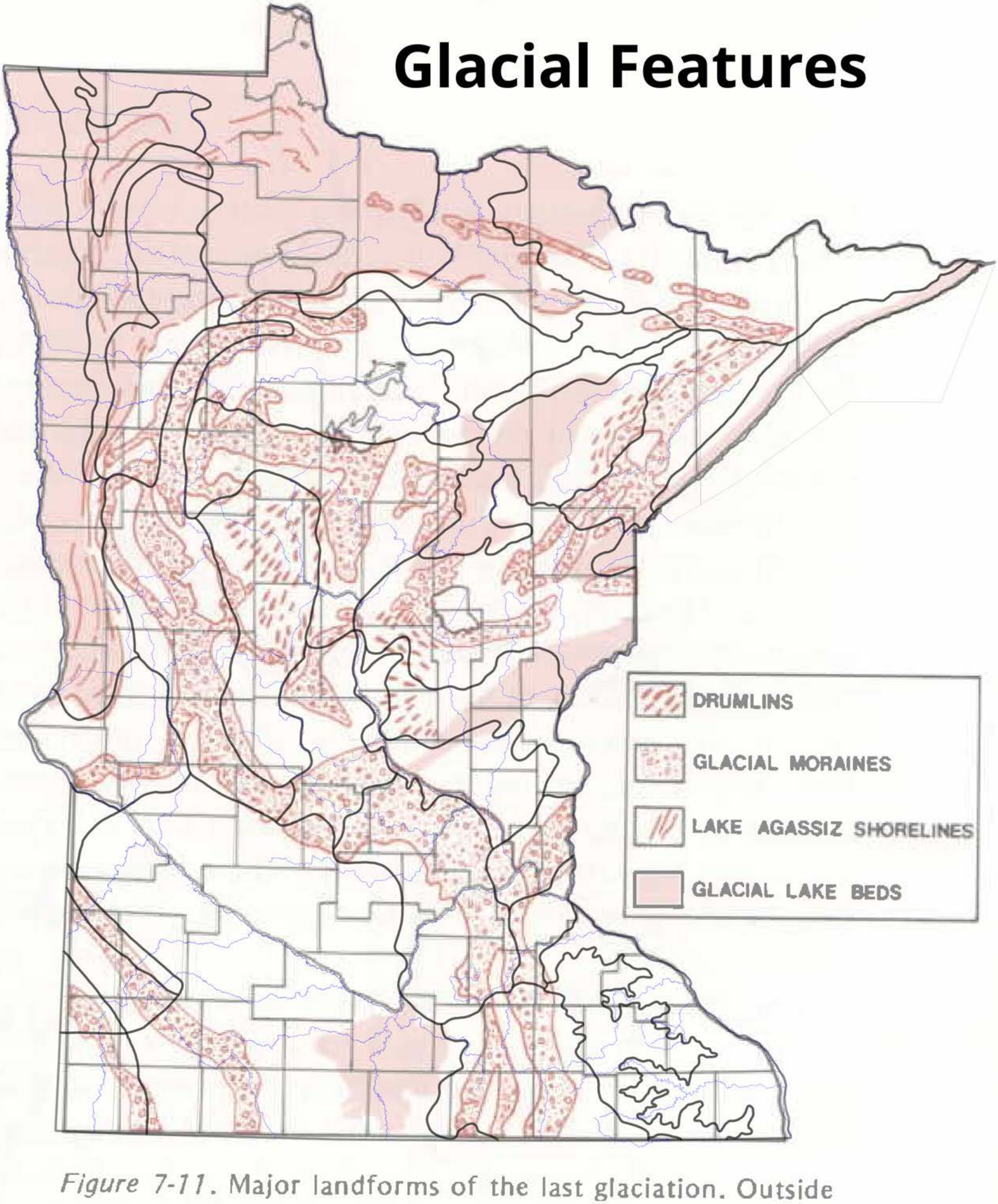
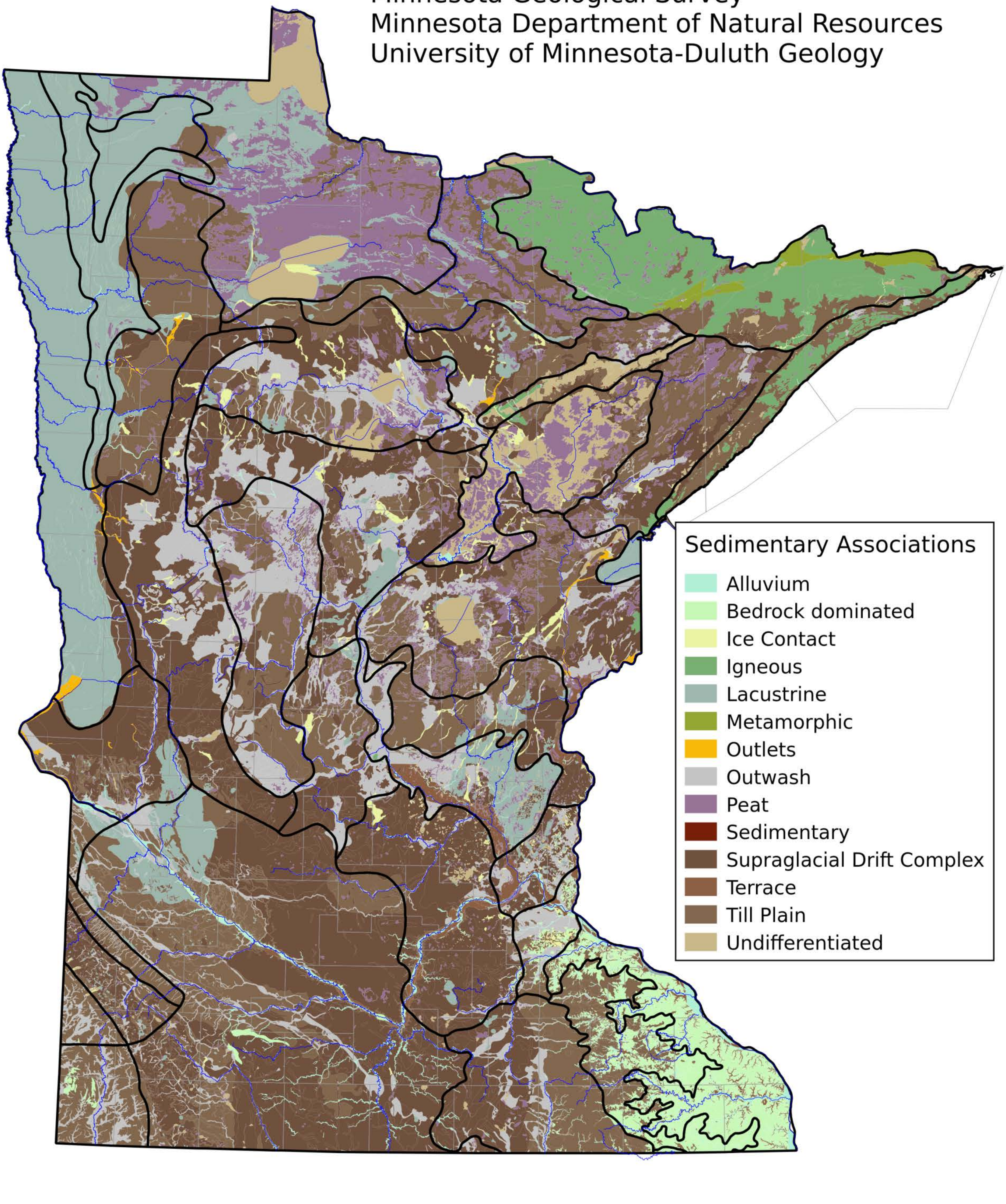


Figure 7-11. Major landforms of the last glaciation. Outside the moraines in the southeast and southwest corners are areas of older drift and bedrock covered by wind-deposited silt (loess).

Ojakangas RW, Matsch CL, Minnesota's Geology, University of Minnesota Press, 1982.

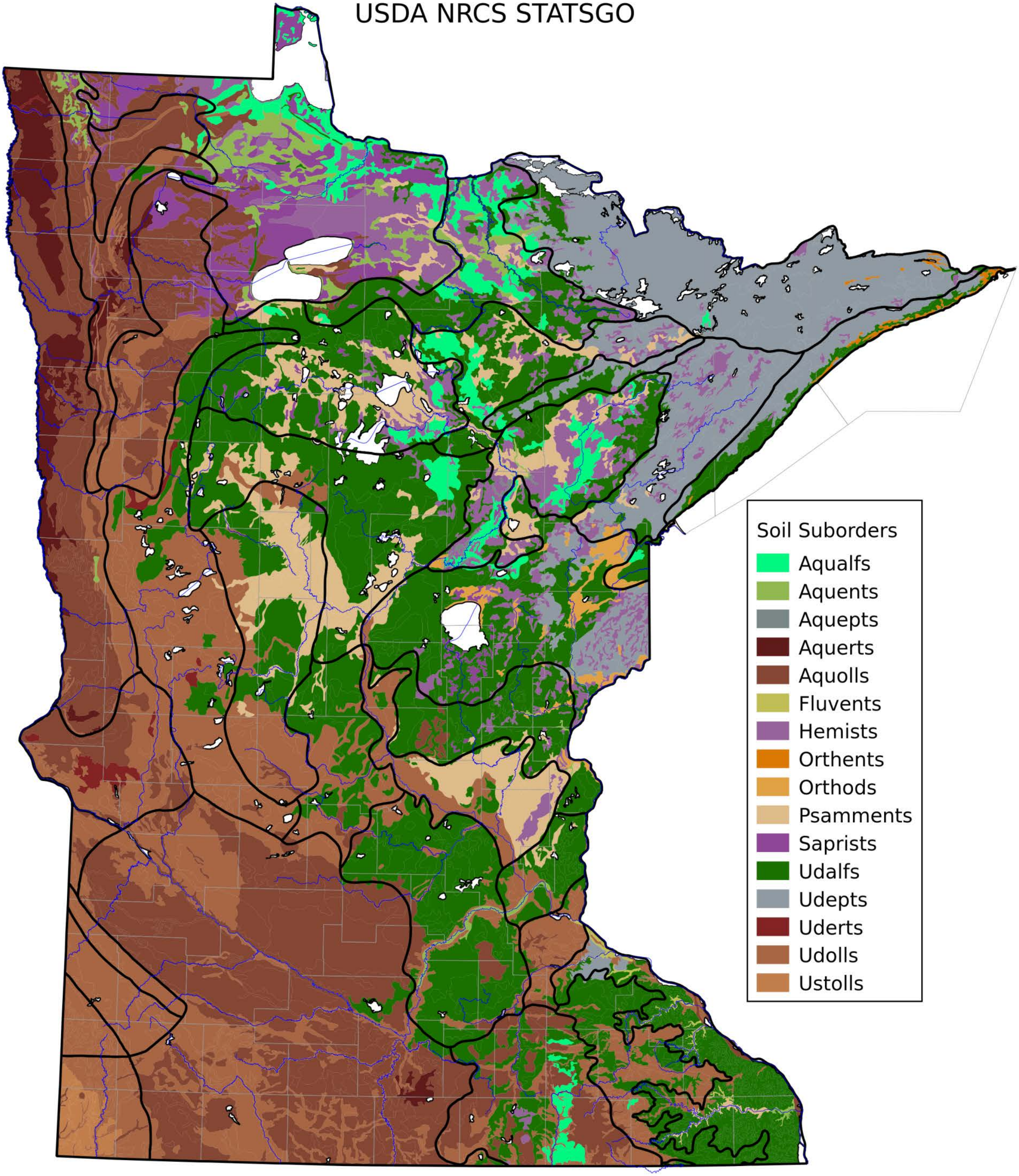
Sedimentary Associations

Minnesota Geological Survey
Minnesota Department of Natural Resources
University of Minnesota-Duluth Geology

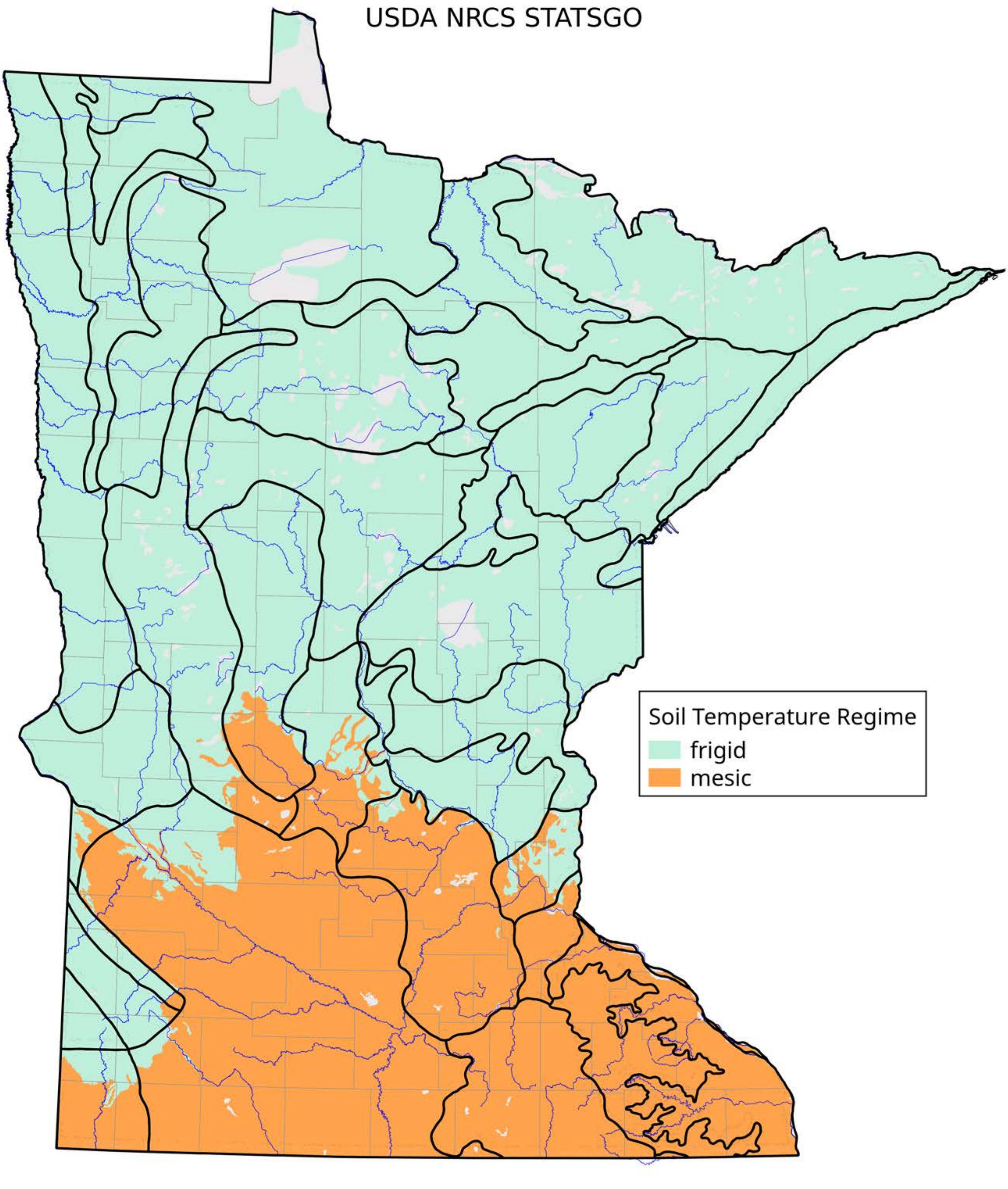


Soil Suborders

USDA NRCS STATSGO

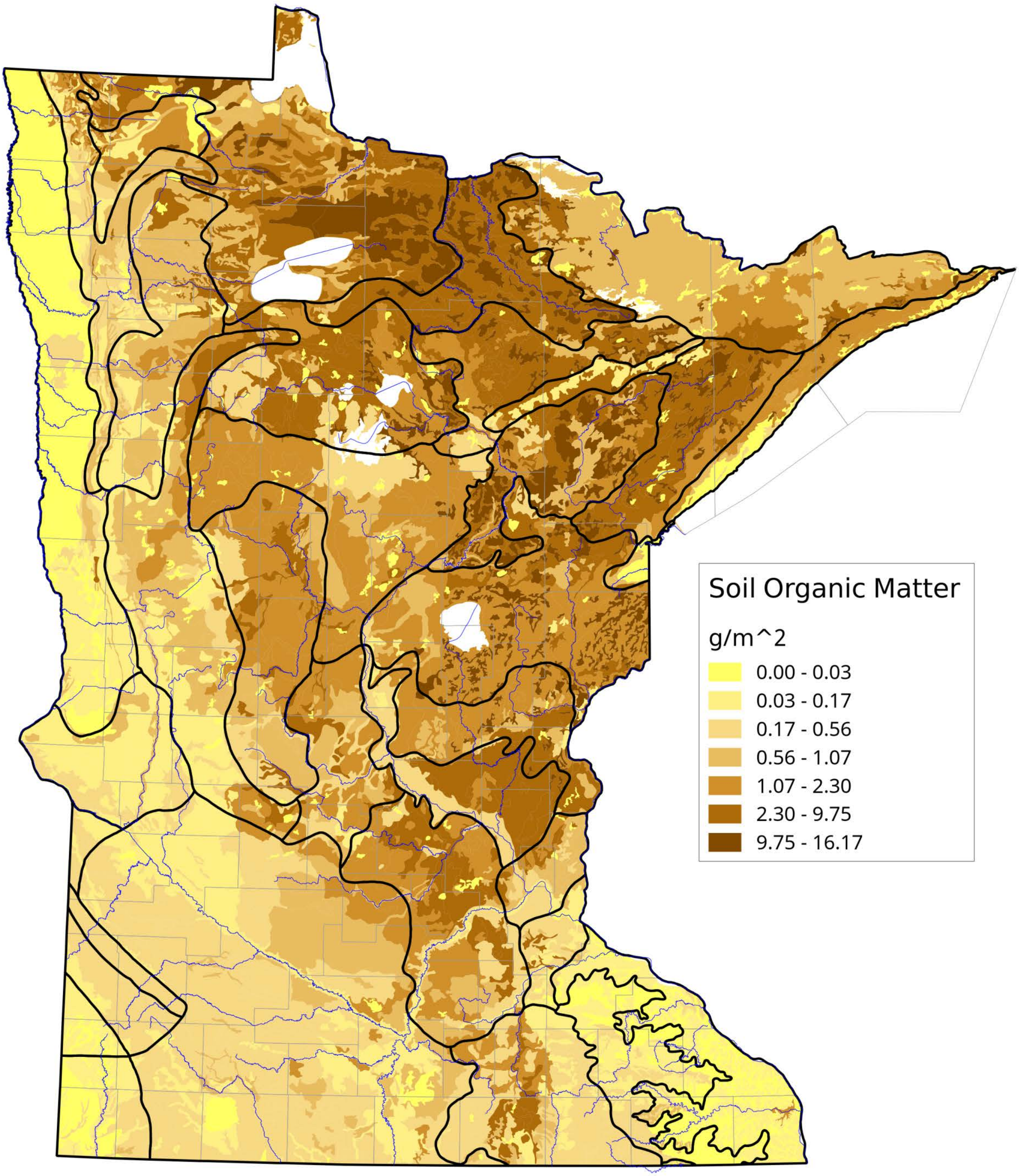


Soil Temperature Regimes



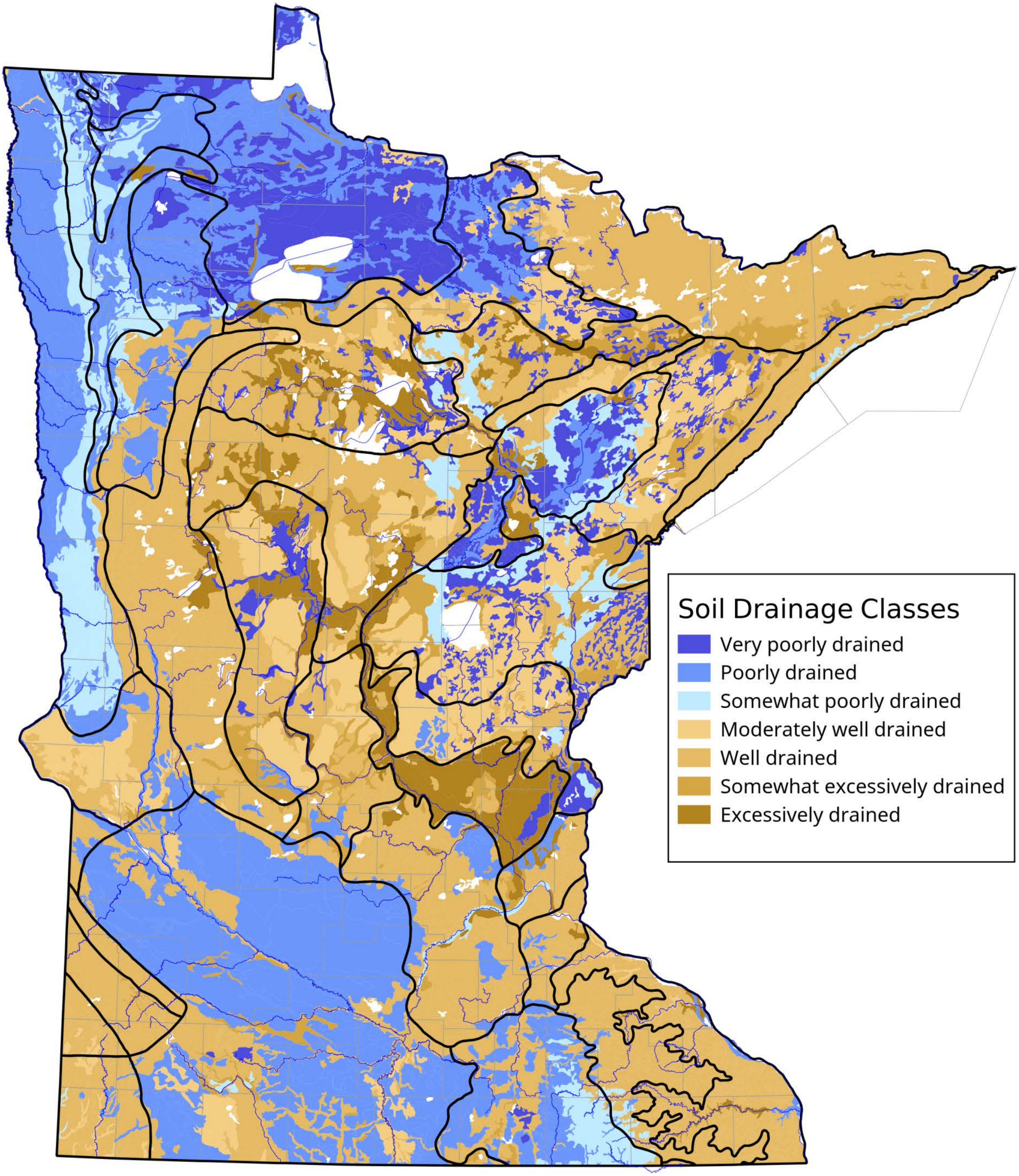
Soil Organic Matter

USDA NRCS STATSGO



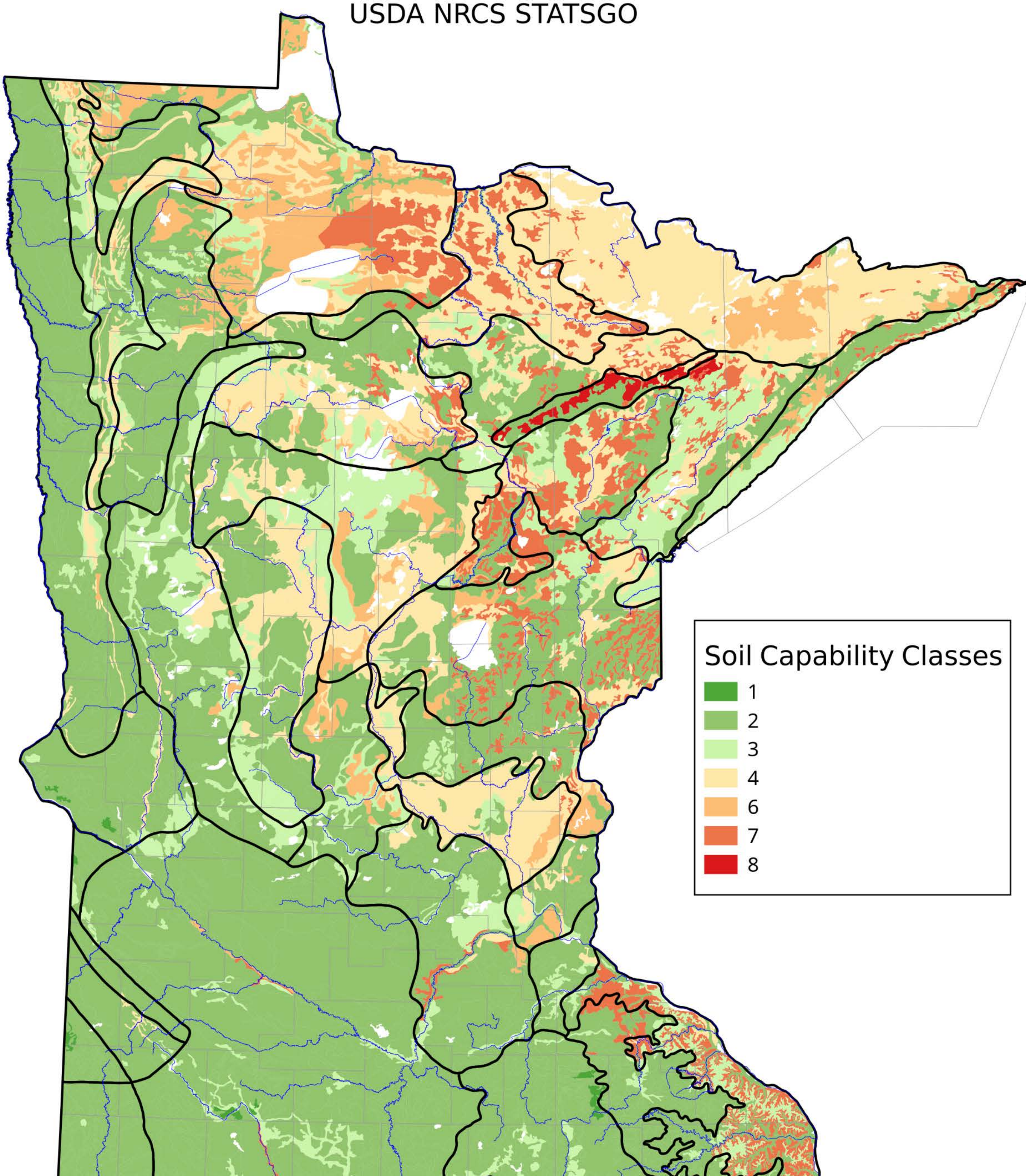
Soil Drainage Classes

USDA NRCS STATSGO

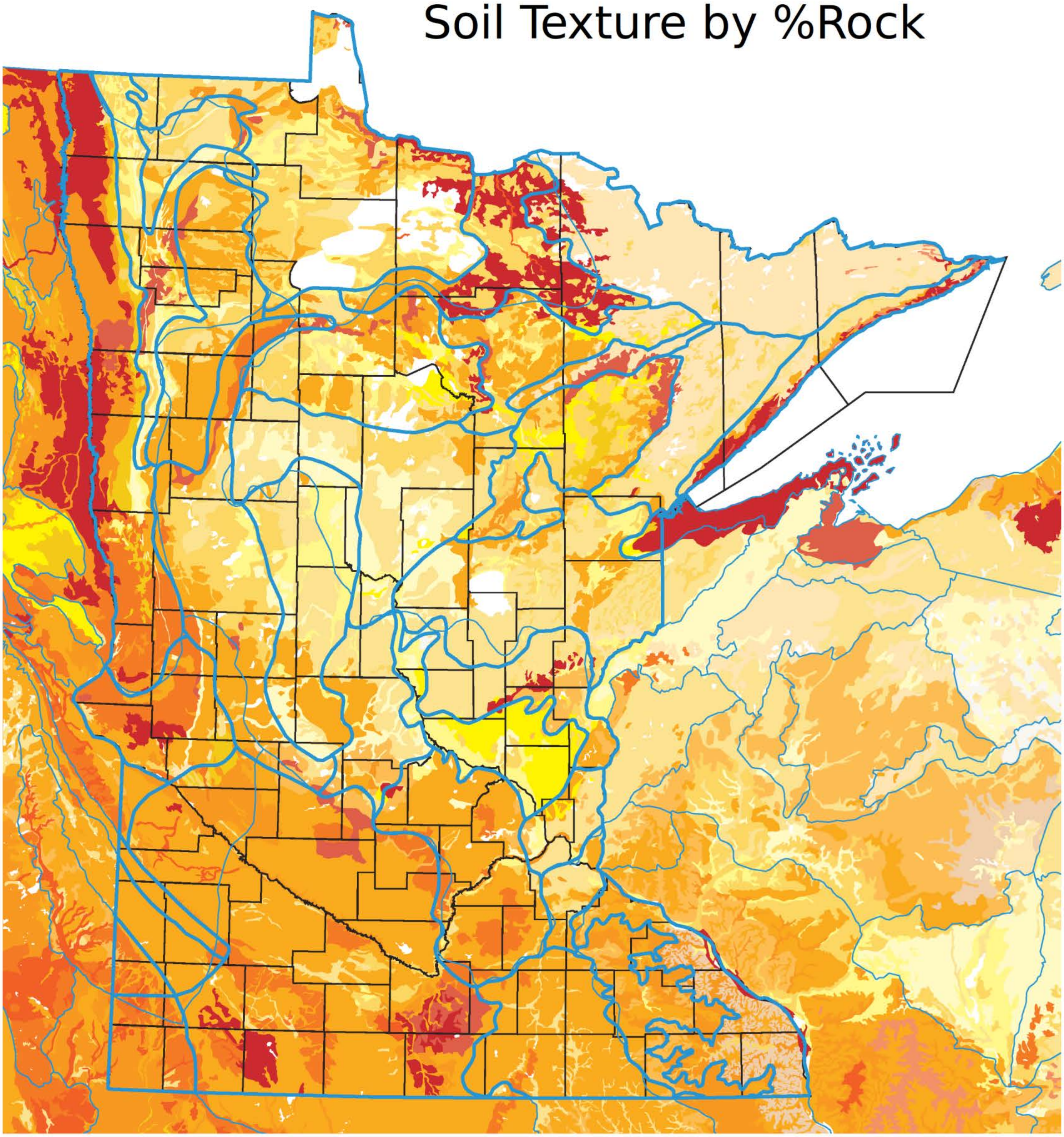


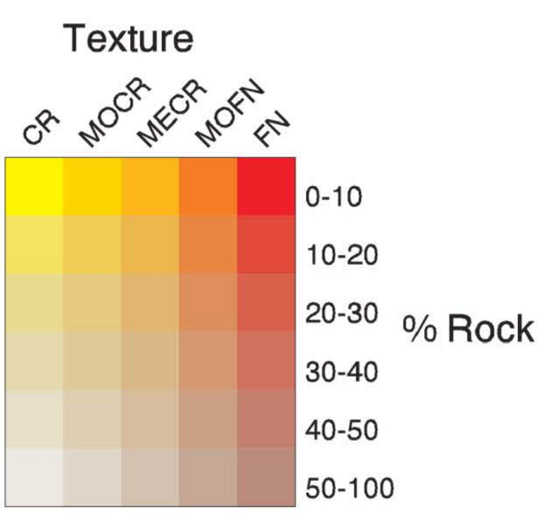
Soil Capability Classes

USDA NRCS STATSGO



Soil Texture by %Rock



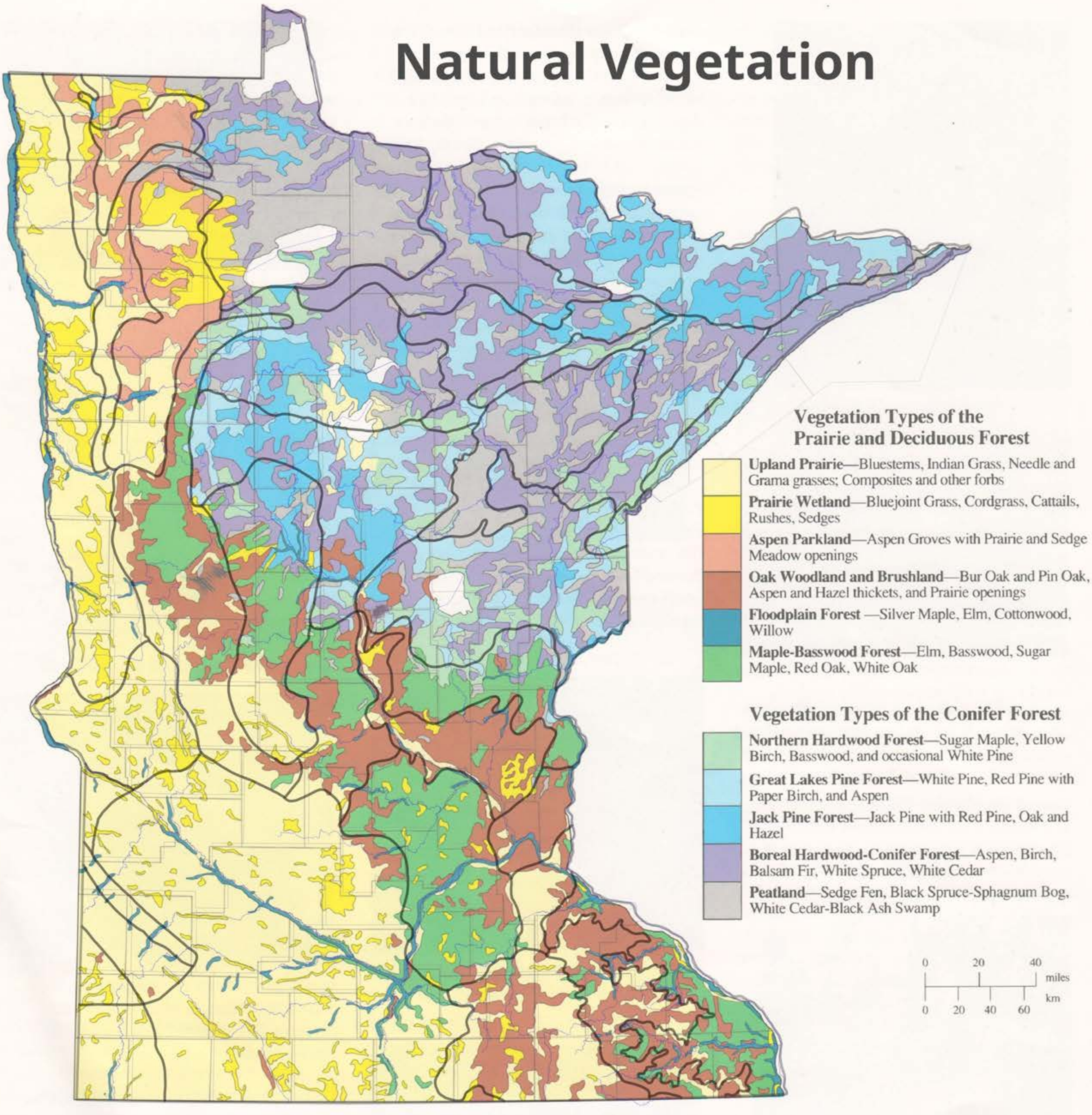


Reference

Shirazi, Mostafa A, Colleen Burch Johnson, James M Omernik, Denis White, Patricia K Haggerty, Glenn E Griffith. 2003. Quantitative soil descriptions for ecoregions of the United States. *Journal of Environmental Quality* 32:550-561.

CR	Coarse
MOCR	Moderately Coarse
MECR	Medium Coarse
MOFN	Moderately Fine
FN	Fine

Natural Vegetation

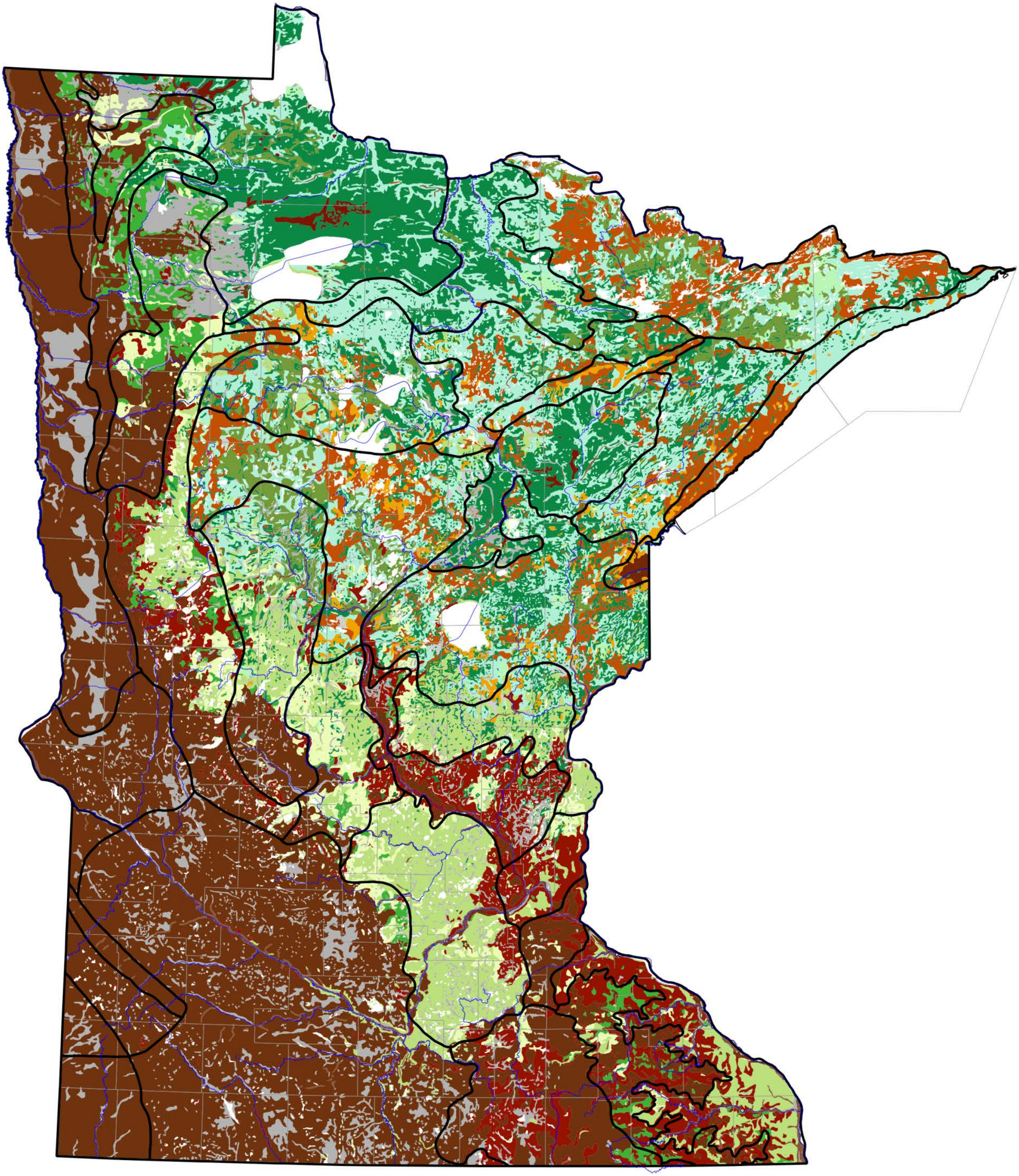


The Natural Vegetation of Minnesota at the Time of the Public Land Survey: 1847-1907

This map was adapted by Barbara Coffin of the DNR, Natural Heritage Program from *The Original Vegetation of Minnesota*, a map compiled in 1930 by F. J. Marschner from the U. S. General Land Office Survey Notes and published in 1974 under the direction of M. L. Heinselman of the U. S. Forest Service. It was produced by the Cartography Laboratory of the Department of Geography, University of Minnesota.

Published by the Natural Heritage Program, Minnesota Department of Natural Resources, 1988©

Presettlement Vegetation
Marschner



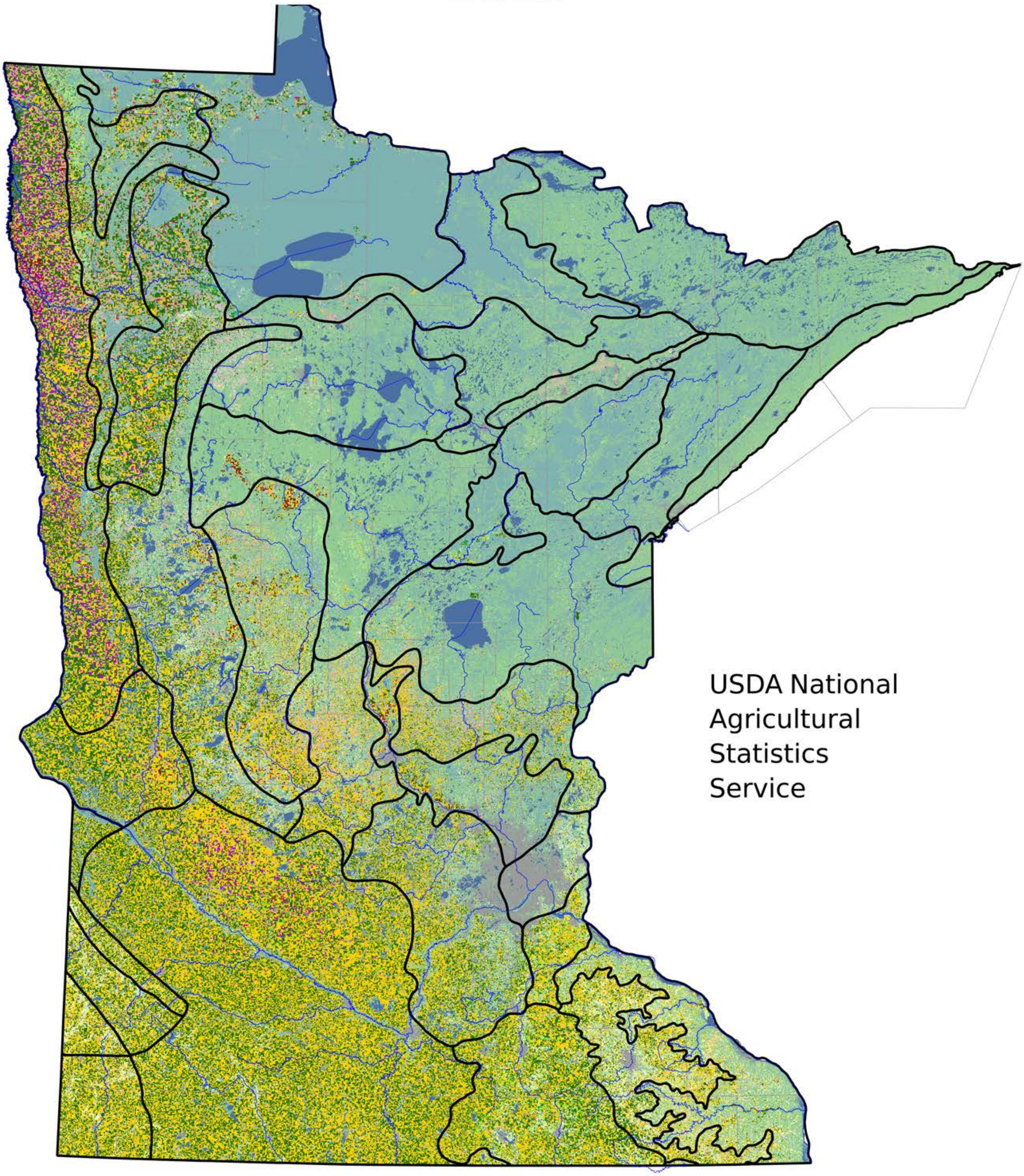
Presettlement Vegetation
Marschner

Legend

Presetttlement Vegetation

- Aspen-Birch (trending to Conifers)
- Aspen-Birch (trending to hardwoods)
- Aspen-Oak Land
- Big Woods - Hardwoods (oak, maple, basswood, hickory)
- Brush Prairie
- Conifer Bogs and Swamps
- Jack Pine Barrens and Openings
- Lakes (open water)
- Mixed Hardwood and Pine (Maple, White Pine, Basswood, etc)
- Mixed White Pine and Red Pine
- Oak openings and barrens
- Open Muskeg
- Pine Flats (Hemlock, Spruce, Fir, White Pine, Aspen)
- Prairie
- River Bottom Forest
- Undefined
- Wet Prairie
- White Pine

Cropland Data Layer
2013



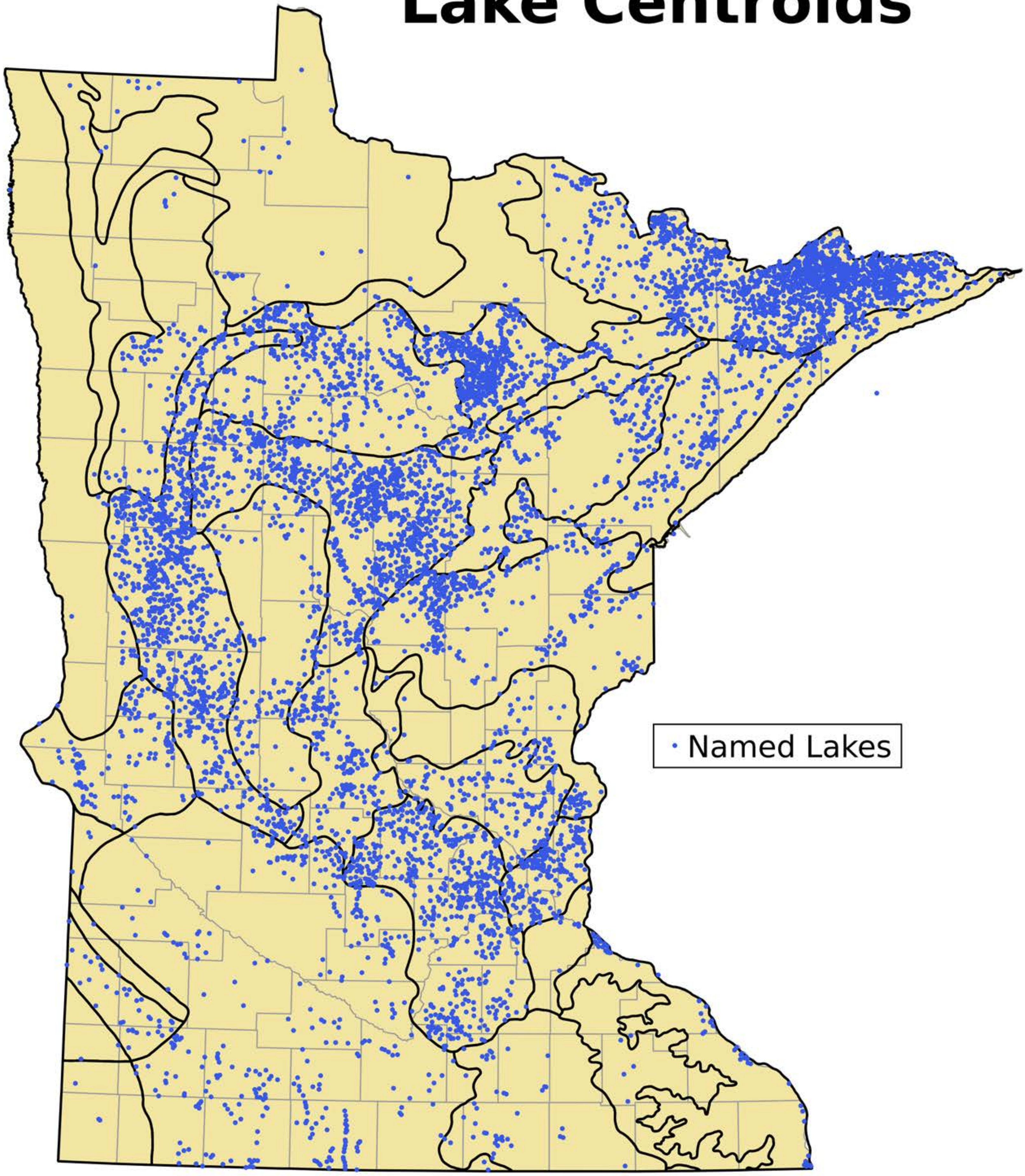
USDA National
Agricultural
Statistics
Service

Cropland Data Layer
2013

Legend

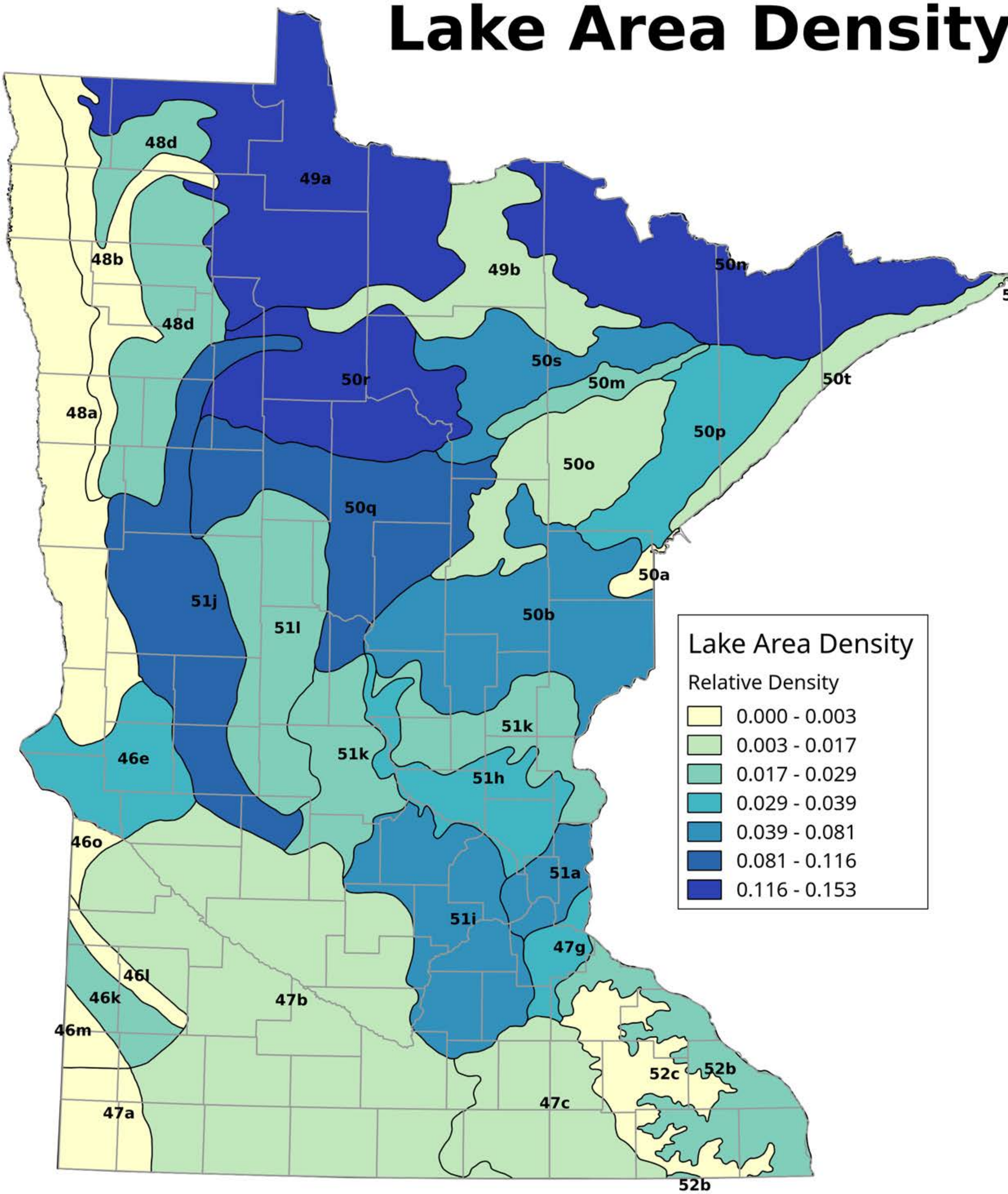
- Corn
- Sorghum
- Soybeans
- Sunflowers
- Sweet Corn
- Barley
- Spring Wheat
- Winter Wheat
- Winter Wheat, Soybeans Double-Cropped
- Rye
- Oats
- Millet
- Canola
- Flaxseed
- Alfalfa
- Other Hays
- Buckwheat
- Sugarbeets
- Dry Beans
- Potatoes
- Other Crops
- Apples
- Peas
- Clover, Wildflowers
- Seed, Sod Grass
- Switchgrass
- Fallow, Idle Cropland
- Open Water
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Shrubland
- Grassland, Pasture
- Woody Wetlands
- Herbaceous Wetlands
- Pistachios
- Triticale
- Carrots
- Pumpkins

Lake Centroids



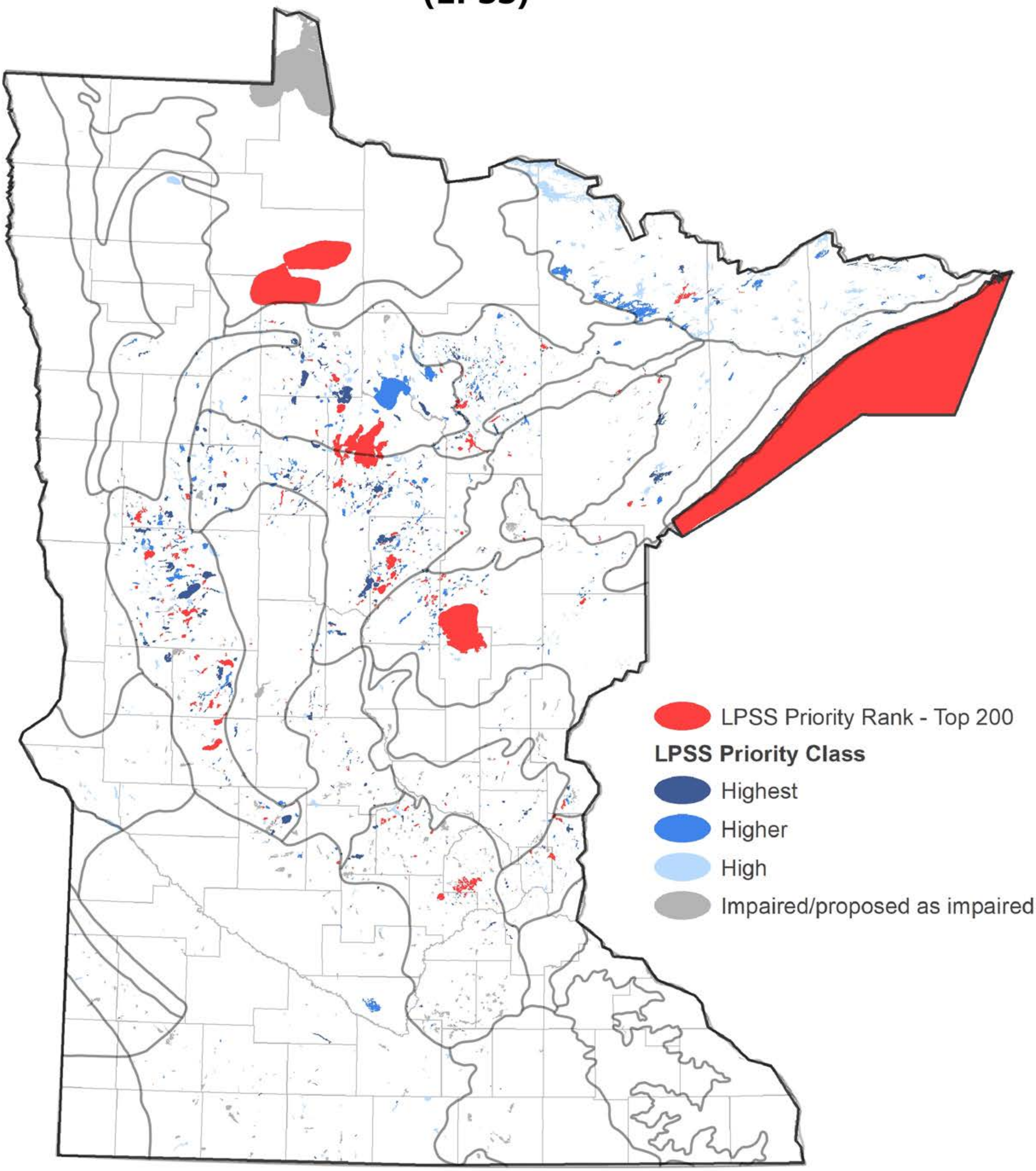
7411 lakes from the DNR Public Waters data that have registered names with GNIS

Lake Area Density



7389 lakes from the DNR Public Waters data that have registered names with GNIS

Lakes of Phosphorus Sensitivity Significance
(LPSS)



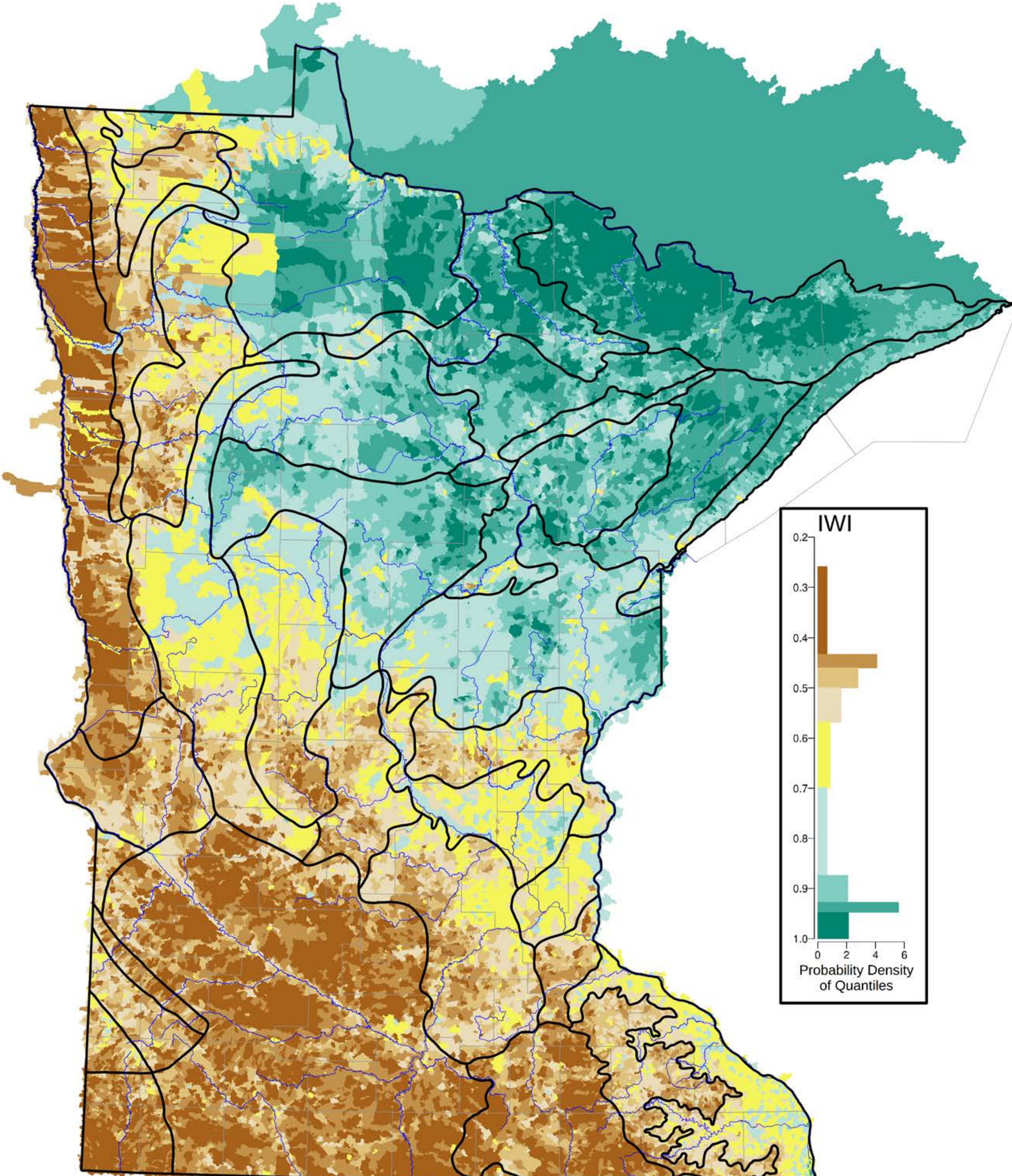
MINNESOTA POLLUTION CONTROL AGENCY

DEPARTMENT OF NATURAL RESOURCES

Minnesota Board of Water & Soil Resources

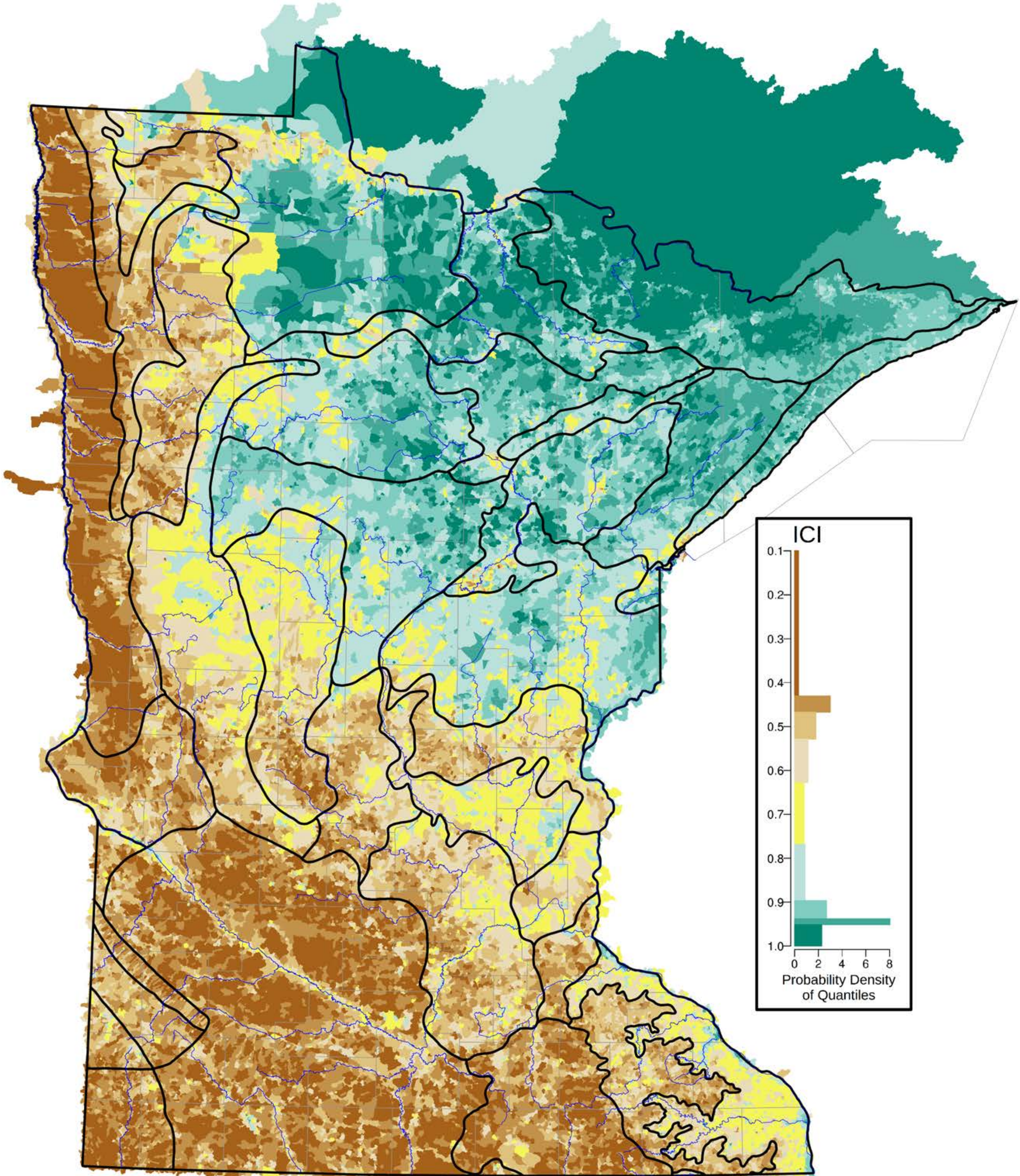
2019

Index of Watershed Integrity



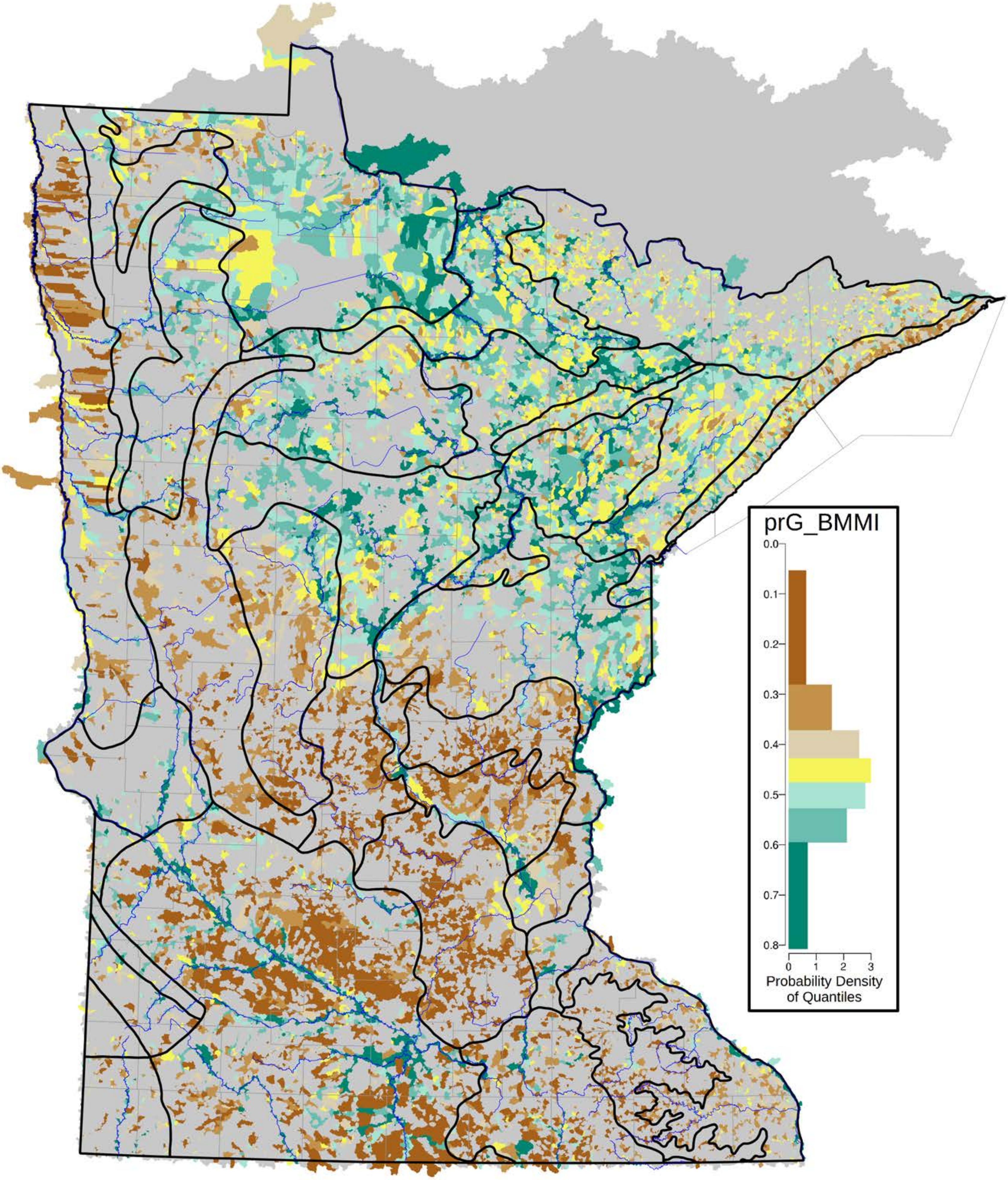
Thornbrugh, Darren, et al. 2018. Mapping watershed integrity for the conterminous United States. Ecological Indicators 85:1133–1148.

Index of Catchment Integrity



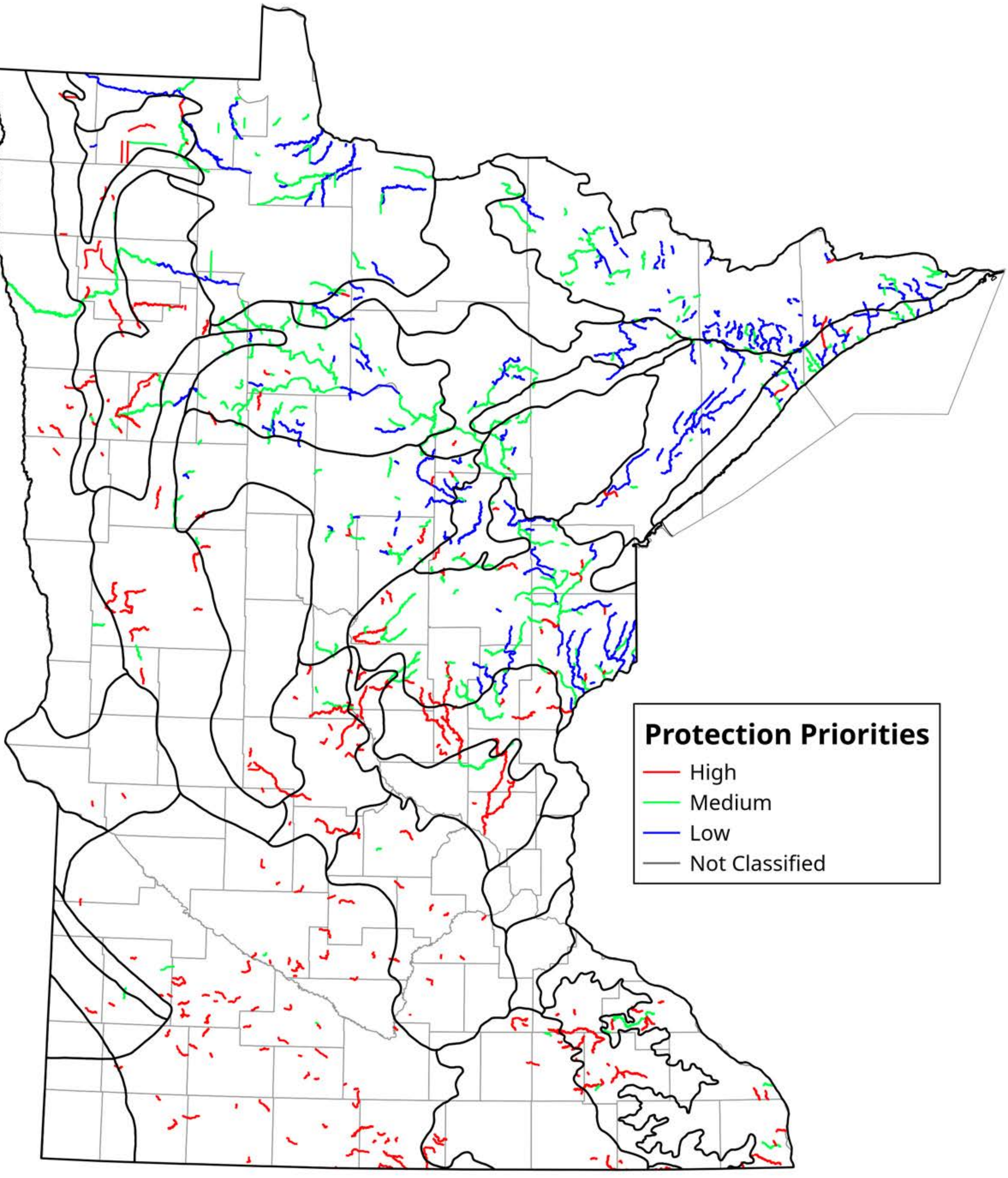
Thornbrugh, Darren, et al. 2018. Mapping watershed integrity for the conterminous United States. Ecological Indicators 85:1133–1148.

Predicted Biotic Condition of Rivers



Hill, Ryan A. et al. 2017. Predictive mapping of the biotic condition of conterminous U.S. rivers and streams. Ecological Applications 27:2397-2415.

Stream Protection Classification

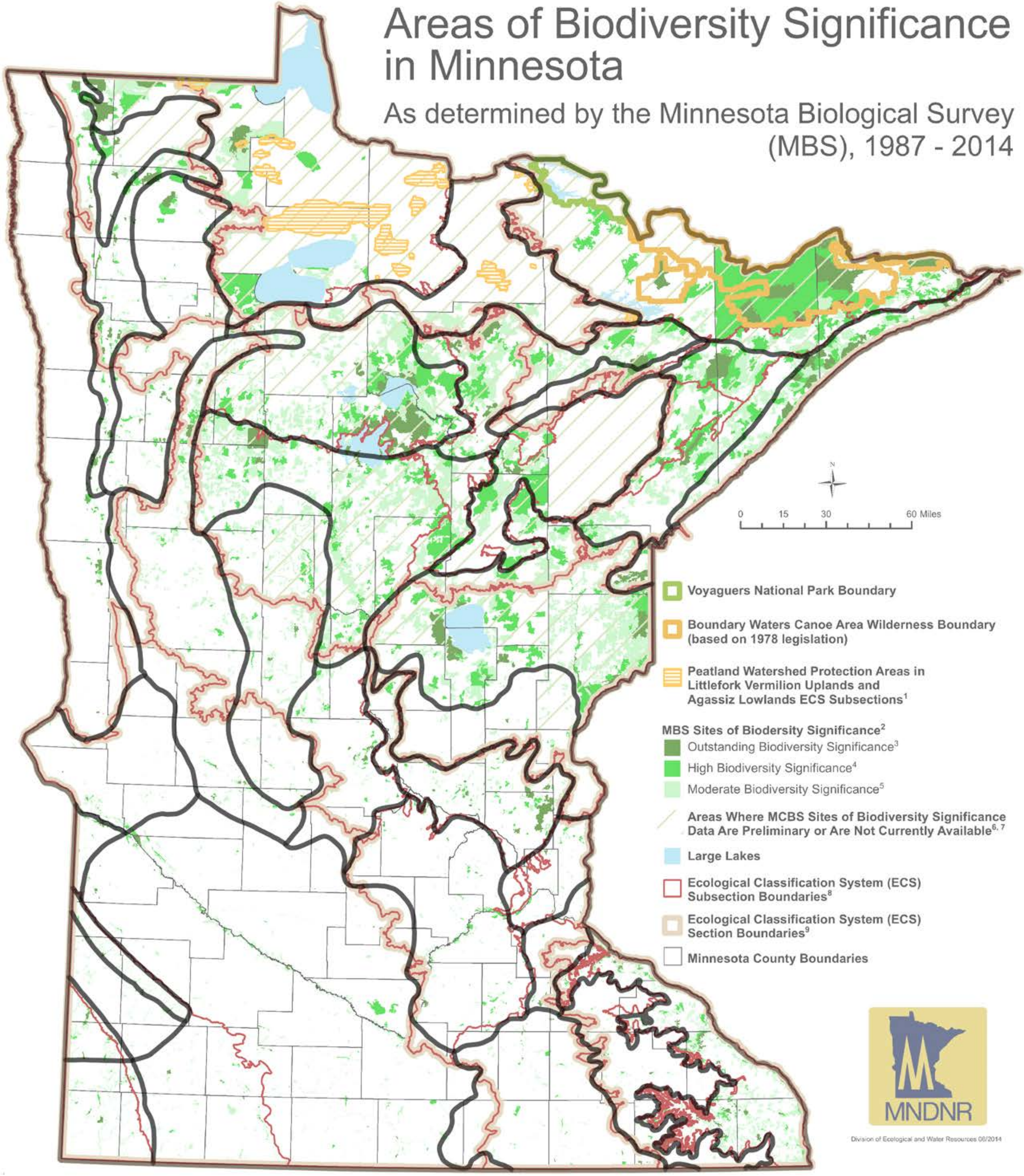


MINNESOTA POLLUTION CONTROL AGENCY

DEPARTMENT OF NATURAL RESOURCES

Minnesota Board of Water & Soil Resources

2019


Areas of Biodiversity Significance in Minnesota
As determined by the Minnesota Biological Survey (MBS), 1987 - 2014
N
0 15 30 60 Miles
Voyaguers National Park Boundary
Boundary Waters Canoe Area Wilderness Boundary (based on 1978 legislation)
Peatland Watershed Protection Areas in Littlefork Vermilion Uplands and Agassiz Lowlands ECS Subsections[1]
MBS Sites of Biodersity Significance[2]
Outstanding Biodiversity Significance[3]
High Biodiversity Significance[4]
Moderate Biodiversity Significance[5]
Areas Where MCBS Sites of Biodiversity Significance Data Are Preliminary or Are Not Currently Available[6, 7]
Large Lakes
Ecological Classification System (ECS) Subsection Boundaries[8]
Ecological Classification System (ECS) Section Boundaries[9]
Minnesota County Boundaries
MNDNR
Division of Ecological and Water Resources 06/2014

MBS Site Biodiversity Significance Ranks

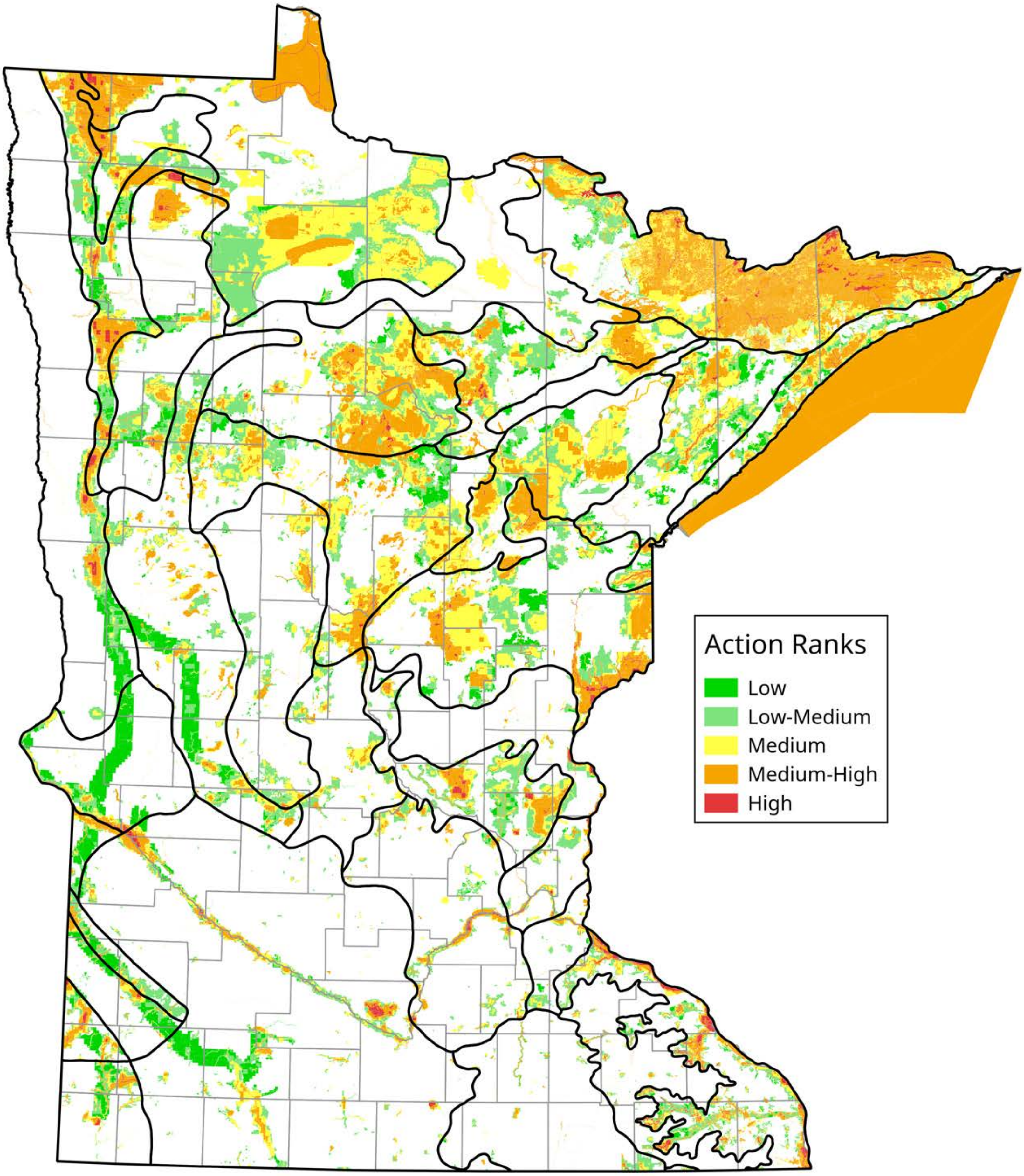
At the conclusion of work in a geographic region, Minnesota Biological Survey (MBS) ecologists assign a biodiversity significance rank to each survey site. These ranks are used to communicate the statewide native biological diversity significance of each site to natural resource professionals, state and local government officials, and the public. The biodiversity ranks help to guide conservation and management.

A site's biodiversity significance rank is based on the presence of rare species populations, the size and condition of native plant communities within the site, and the landscape context of the site (for example, whether the site is isolated in a landscape dominated by cropland or developed land, or whether it is connected or close to other areas with intact native plant communities).

There are four biodiversity significance ranks, outstanding, high, moderate, and below:

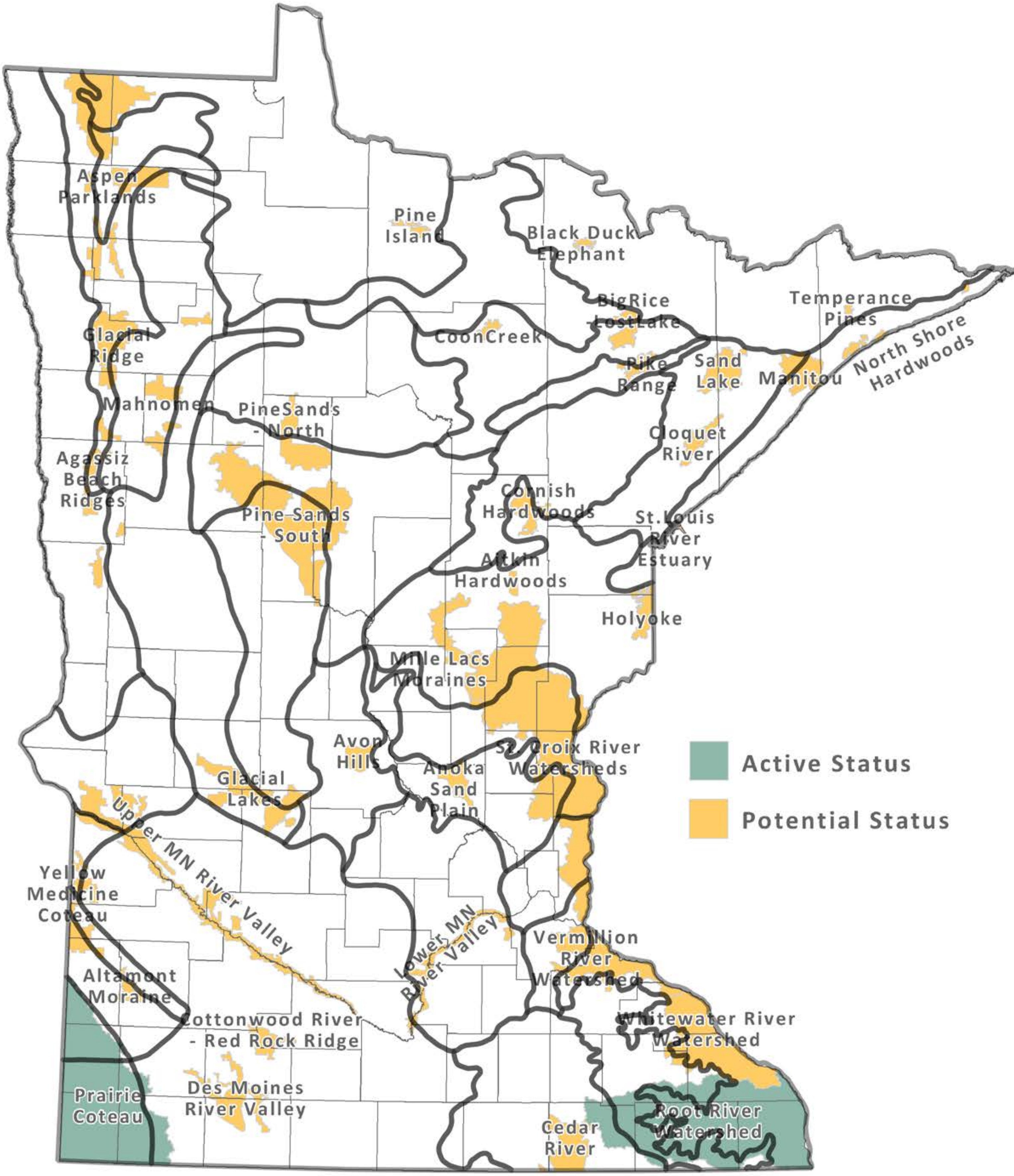
- "**Outstanding**" sites contain the best occurrences of the rarest species, the most outstanding examples of the rarest native plant communities, and/or the largest, most ecologically intact or functional landscapes.
- "**High**" sites contain very good quality occurrences of the rarest species, high-quality examples of rare native plant communities, and/or important functional landscapes.
- "**Moderate**" sites contain occurrences of rare species, moderately disturbed native plant communities, and/or landscapes that have strong potential for recovery of native plant communities and characteristic ecological processes.
- "**Below**" sites lack occurrences of rare species and natural features or do not meet MBS standards for outstanding, high, or moderate rank. These sites may include areas of conservation value at the local level, such as habitat for native plants and animals, corridors for animal movement, buffers surrounding higher-quality natural areas, areas with high potential for restoration of native habitat, or open space.

Minnesota's Wildlife Action Plan 2015-2025
Wildlife Action Network



Minnesota Department of Natural Resources

Conservation Focus Areas (CFA) Status
2015 - 2025 MN Wildlife Action Plan

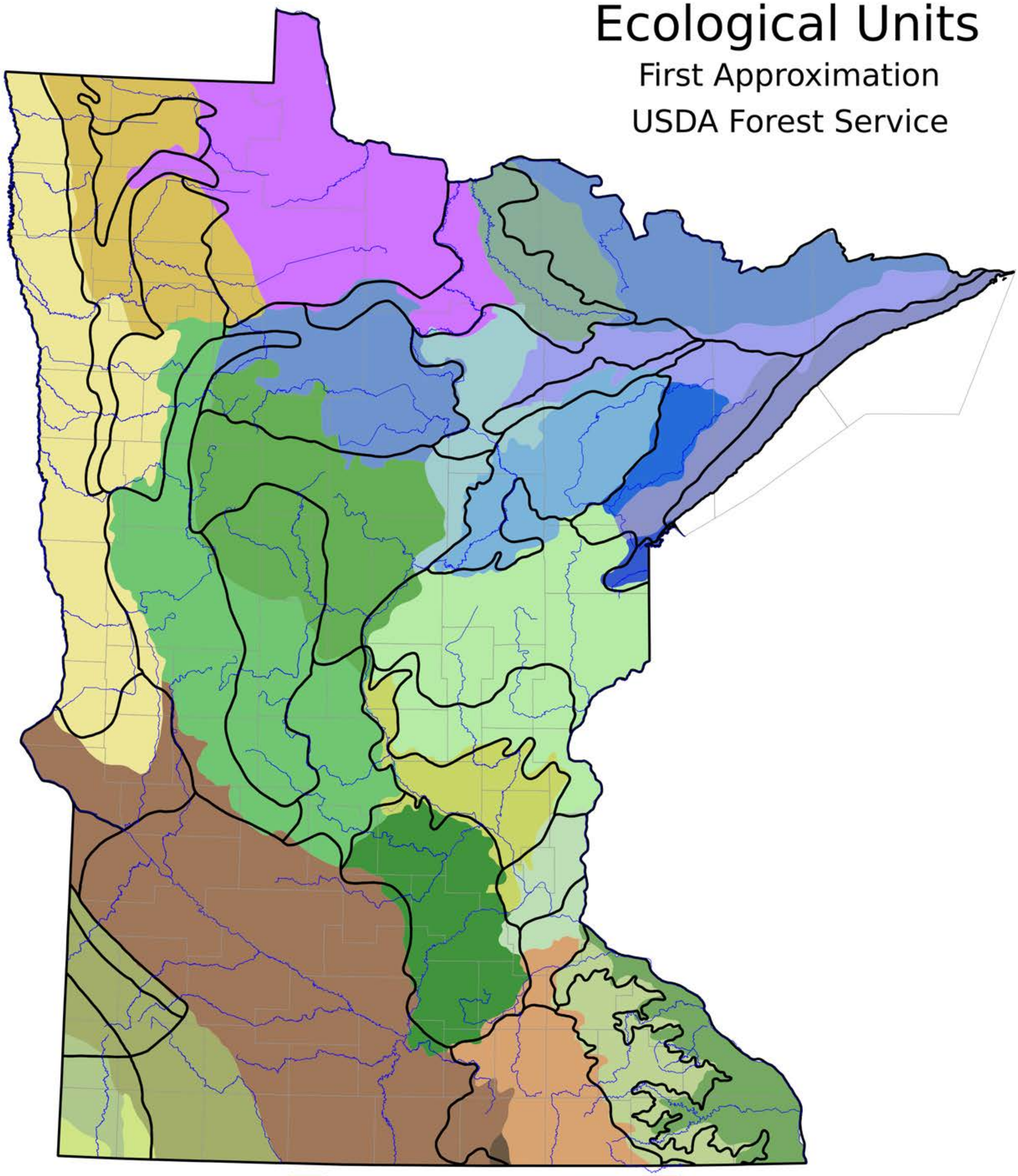


DEPARTMENT OF NATURAL RESOURCES

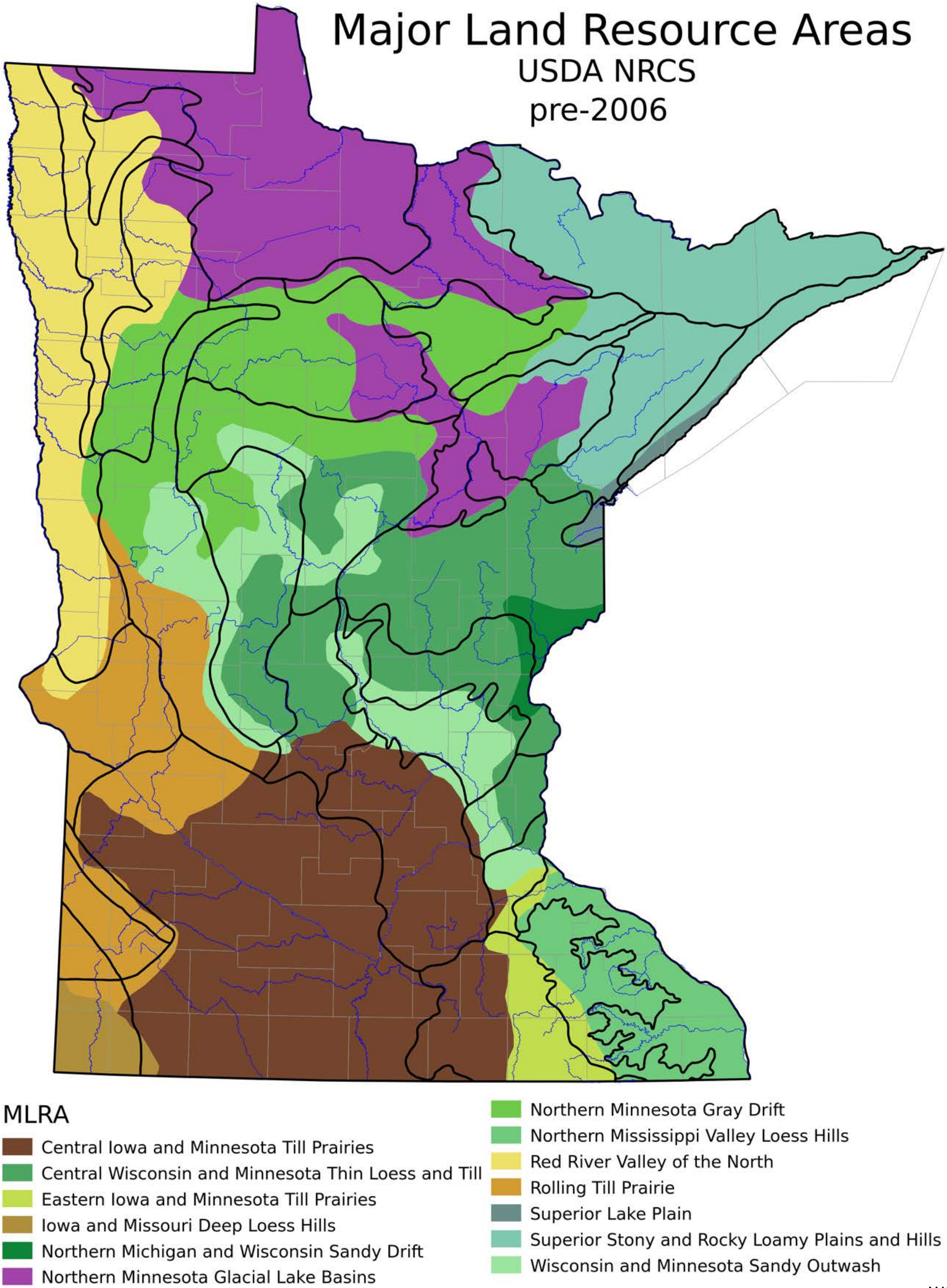
Ecological Units

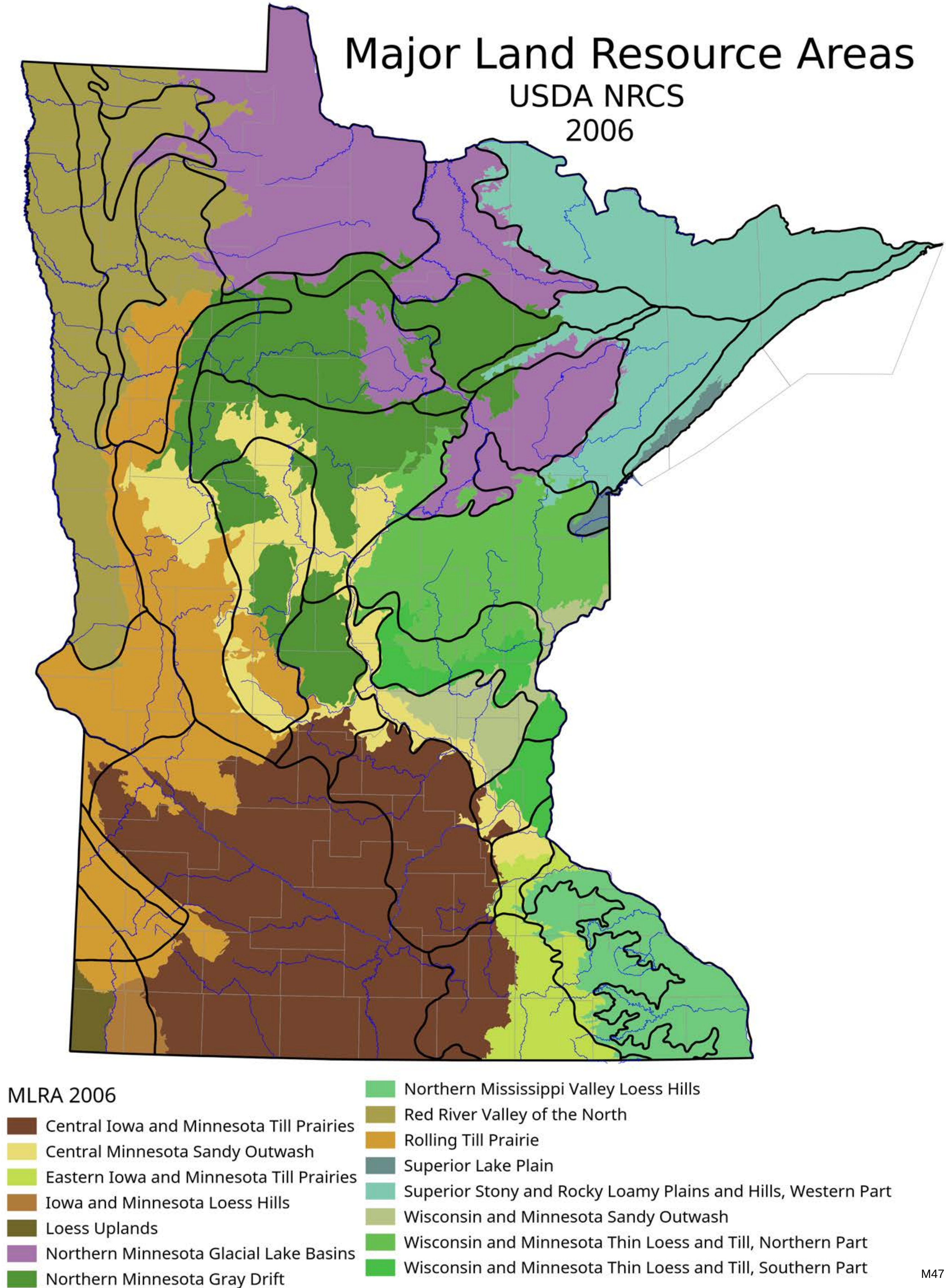
First Approximation

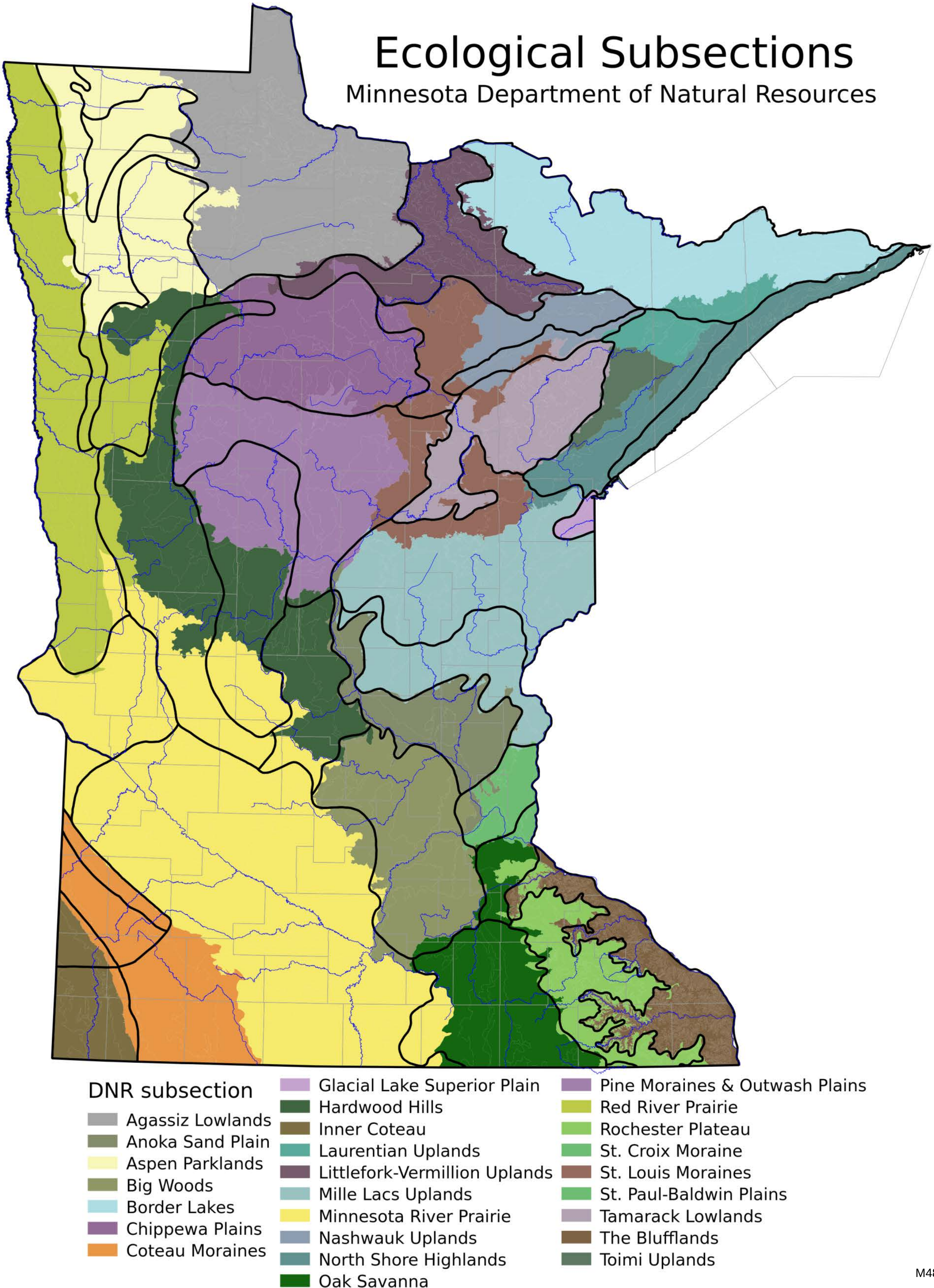
USDA Forest Service



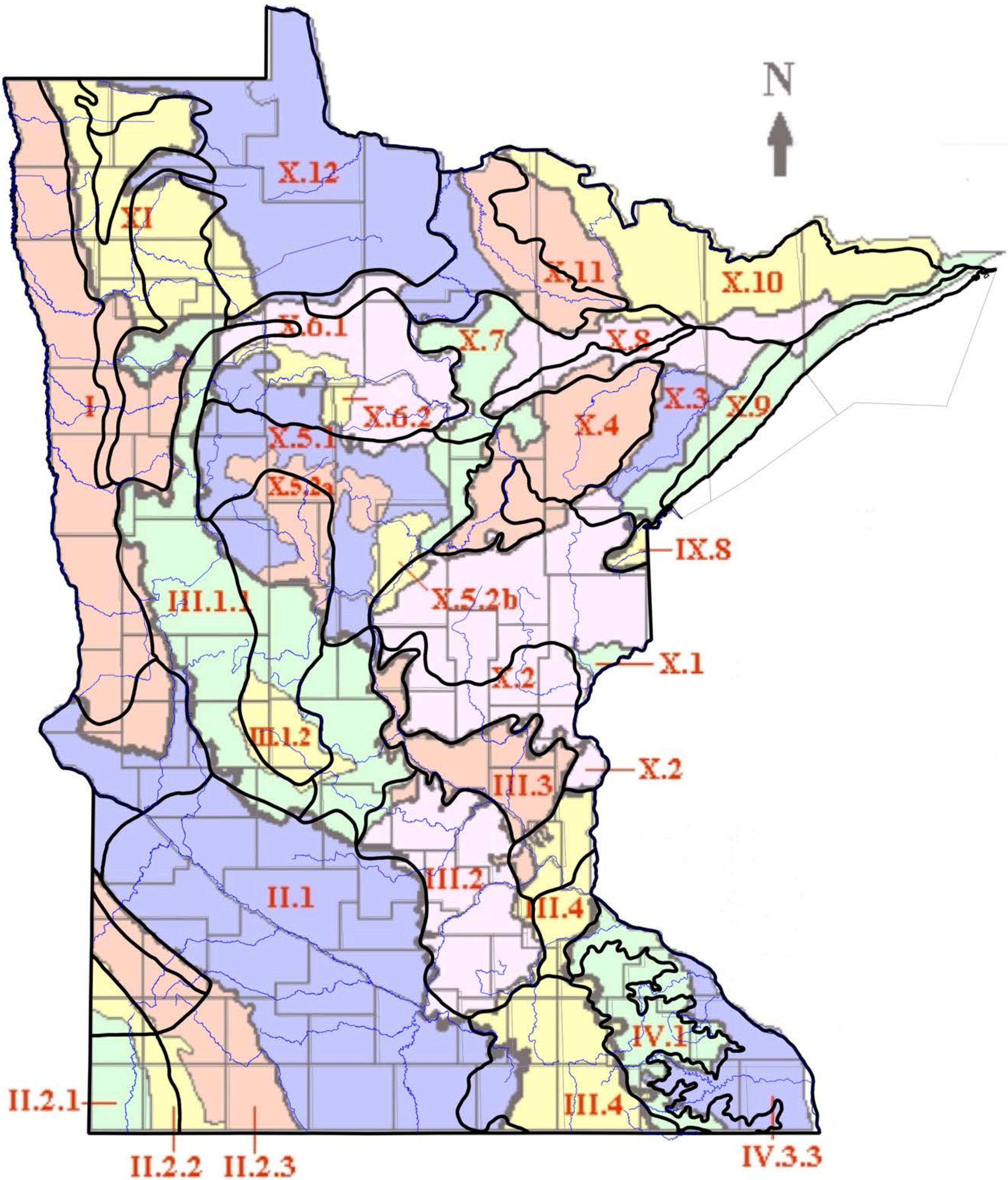
Major Land Resource Areas
USDA NRCS
pre-2006




Major Land Resource Areas
USDA NRCS
2006
MLRA 2006
Central Iowa and Minnesota Till Prairies
Central Minnesota Sandy Outwash
Eastern Iowa and Minnesota Till Prairies
Iowa and Minnesota Loess Hills
Loess Uplands
Northern Minnesota Glacial Lake Basins
Northern Minnesota Gray Drift
Northern Mississippi Valley Loess Hills
Red River Valley of the North
Rolling Till Prairie
Superior Lake Plain
Superior Stony and Rocky Loamy Plains and Hills, Western Part
Wisconsin and Minnesota Sandy Outwash
Wisconsin and Minnesota Thin Loess and Till, Northern Part
Wisconsin and Minnesota Thin Loess and Till, Southern Part


Ecological Subsections
Minnesota Department of Natural Resources
DNR subsection
Agassiz Lowlands
Anoka Sand Plain
Aspen Parklands
Big Woods
Border Lakes
Chippewa Plains
Coteau Moraines
Glacial Lake Superior Plain
Hardwood Hills
Inner Coteau
Laurentian Uplands
Littlefork-Vermillion Uplands
Mille Lacs Uplands
Minnesota River Prairie
Nashwauk Uplands
North Shore Highlands
Oak Savanna
Pine Moraines & Outwash Plains
Red River Prairie
Rochester Plateau
St. Croix Moraine
St. Louis Moraines
St. Paul-Baldwin Plains
Tamarack Lowlands
The Blufflands
Toimi Uplands

Landscape Ecosystems



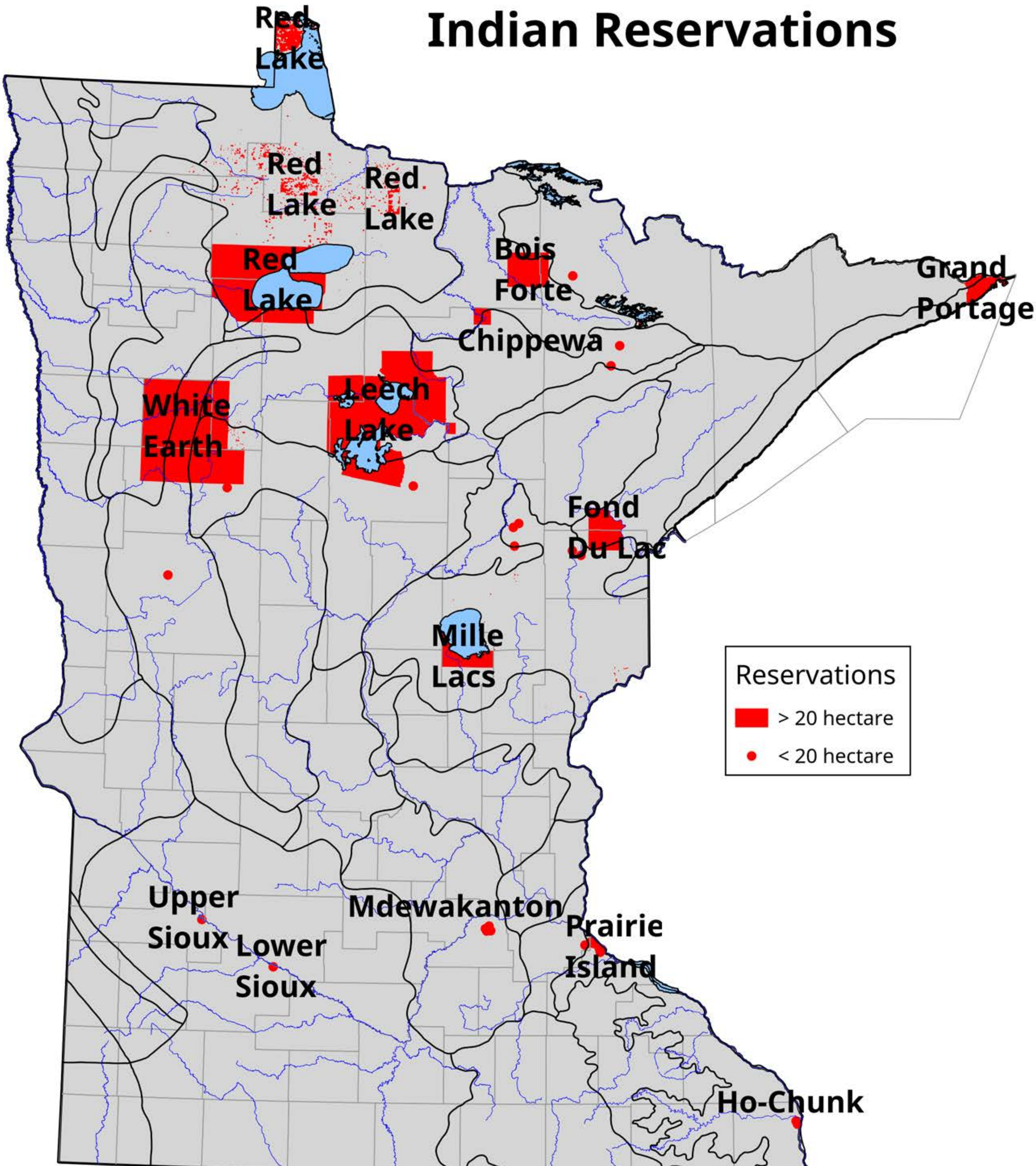
Albert, USDA Forest Service GTR NC-178, 1995

Landscape Ecosystems

Dennis Albert, USDA Forest Service, General Technical Report, NC-178, 1995

- Section I. Northwestern Minnesota Grassland
- 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 Michigan, 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-Vermillion Uplands
  - Subsection X.12. Agassiz Lowlands
- Section XI. Aspen Parkland

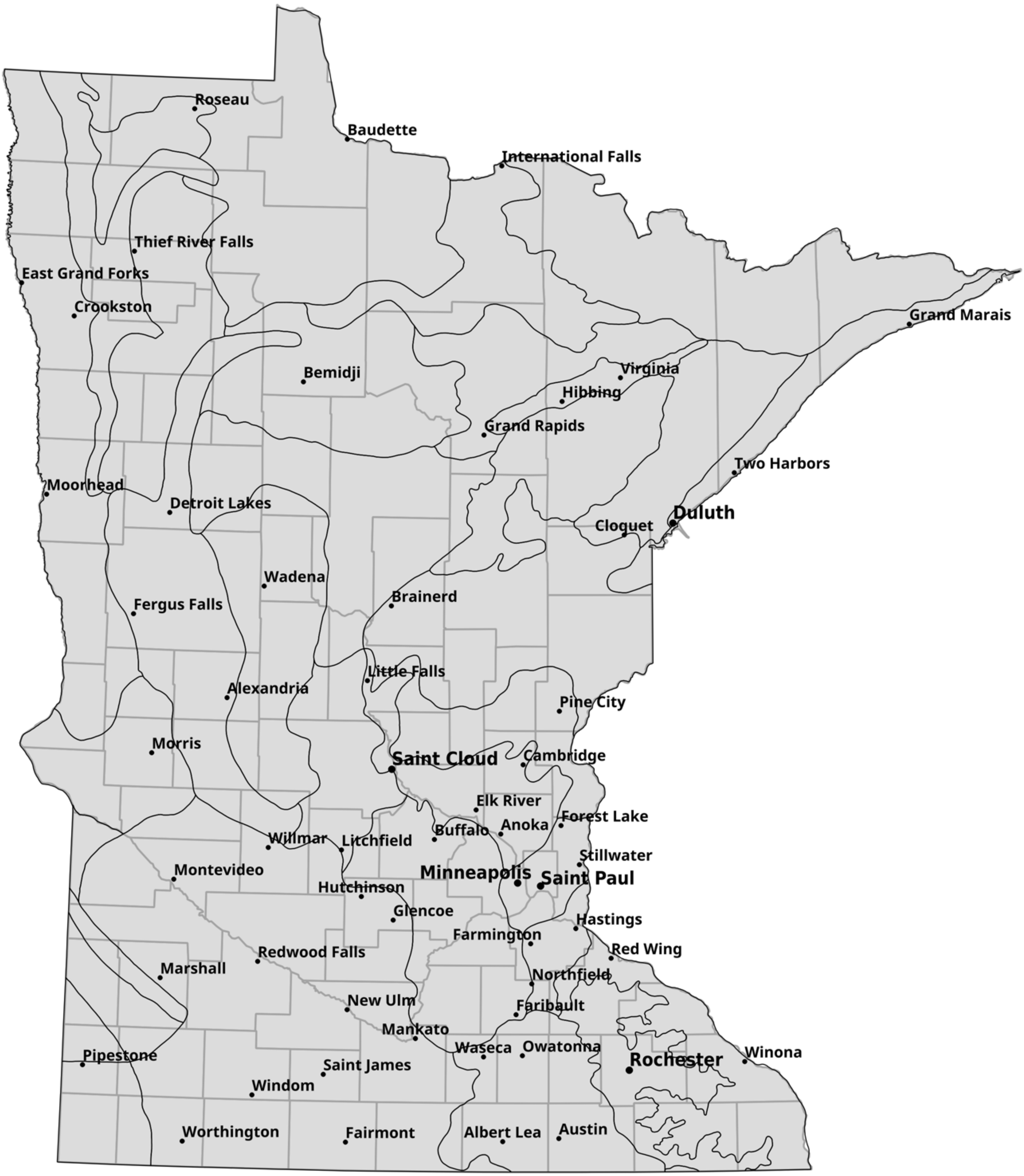
Indian Reservations



Small dot symbols without names are part of named reservations

Lakes, Rivers

Cities


Roseau
Baudette
International Falls
Thief River Falls
East Grand Forks
Crookston
Grand Marais
Bemidji
Virginia
Hibbing
Grand Rapids
Two Harbors
Moorhead
Detroit Lakes
Duluth
Cloquet
Wadena
Brainerd
Fergus Falls
Little Falls
Alexandria
Pine City
Morris
Saint Cloud
Cambridge
Elk River
Forest Lake
Anoka
Buffalo
Willmar
Litchfield
Stillwater
Montevideo
Minneapolis
Saint Paul
Hutchinson
Glencoe
Hastings
Farmington
Red Wing
Redwood Falls
Marshall
Northfield
New Ulm
Faribault
Mankato
Waseca
Owatonna
Winona
Pipestone
Rochester
Saint James
Windom
Worthington
Fairmont
Albert Lea
Austin

M53

Counties

M54

Appendix S

Descriptions of Soil Orders and Suborders

Extracted from:
Soil Survey Staff. 2015. Illustrated guide to soil taxonomy, version 2. U.S. Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, Nebraska.

Order Alfisols are naturally fertile soils with high base saturation and a clay-enriched subsoil horizon.

Suborder Aqualfs are the wet Alfisols. They are saturated close to the surface by ground water for a long enough period during the year to become devoid of oxygen (aquic conditions). Some are artificially drained. Aqualfs occur in low landscape positions, such as flood plains, depressions, and broad flats. A few may be on side slopes where water seeps laterally over restrictive layers to the surface. Many Aqualfs are drained and used for cultivated crops.

Suborder Udalfs are the more or less freely drained Alfisols that have seasonally well-distributed precipitation (udic moisture regime) and cold to warm temperature regimes. These soils are principally but not entirely in areas of late-Pleistocene deposits and erosional surfaces of about the same age. Most Udalfs with a mesic or warmer temperature regime have or had deciduous forest vegetation, and many with a frigid temperature regime have or had mixed coniferous and deciduous forest vegetation. Many Udalfs have been cleared of trees and are intensively farmed.

Order Entisols are young soils with little or no soil profile development.

Suborder Aquents are the wet Entisols. They are saturated close to the surface for a long enough period during the year to become devoid of oxygen (aquic conditions). Some are artificially drained. Aquents commonly occur in wetlands, such as in tidal marshes, on deltas, on the margins of lakes (where the soils are continuously saturated with water), on flood plains along streams (where the soils are saturated at some time of the year), and in areas of wet, sandy deposits.

Suborder Fluvents are mostly brownish to reddish soils that formed in recent water-deposited sediments, mainly on flood plains, fans, and deltas of rivers and small streams but not in backswamps, where drainage is poor. Many Fluvents are frequently flooded unless they are protected by dams or levees. In humid regions, the age of the sediments is commonly a few years or decades or a very few hundred years.

Suborder Orthents are primarily the Entisols on recent erosional surfaces. The erosion may have been geologic or been human-induced by cultivation, mining, or other activities. Any former soil that was on the landscape before accelerated erosion began has been completely removed or so truncated that the diagnostic horizons for all other soil orders do not occur.

Suborder Psamments are the sandy Entisols with < 35% rock fragments. They are sandy in all layers, generally to a depth of 100 cm or more. Some formed in poorly graded (well sorted) sands on shifting or stabilized sand dunes, in cover sands, or in sandy parent materials that were sorted in an earlier geologic cycle. Some formed in sands that were sorted by water and are on outwash plains, lake plains, natural levees, or beaches. A few Psamments formed in material weathered from sandstone or granitic bedrock.

Order Histosols are soils that formed in decaying organic material.

Suborder Hemists are the wet Histosols in which the organic materials are moderately decomposed. Ground water is at or very close to the soil surface much of the time unless artificial drainage is provided. They are in closed depressions and in broad flat areas, such as coastal plains and outwash plains. Most Hemists are under natural vegetation and are used as woodland, rangeland, or wildlife habitat. Some large areas of Hemists are cleared, drained, and used as cropland.

Suborder Saprists are the wet Histosols in which the organic materials are well decomposed. Saprists occur in areas where the ground-water table tends to fluctuate within the soil or in areas where the soil was aerobic during drier periods in the past. They consist of the residue that remains after the aerobic decomposition of organic matter.

Order Inceptisols are youthful soils with a weak, but noticeable, degree of profile development.

Suborder Aquepts are the wet Inceptisols. These soils have poor or very poor natural drainage. If the soils are not artificially drained, ground water is at or near the soil surface at some time during most years but typically not during all seasons. Most Aquepts formed in late-Pleistocene or younger deposits in depressions, on nearly level plains, or on flood plains.

Suborder Udepts are mainly the more or less freely drained Inceptisols of humid climates. They formed on nearly level to steep surfaces, mostly of late-Pleistocene or Holocene age. Most of the soils had or now have forest vegetation, but some support shrubs or grasses. A few formed from Mollisols by human-induced erosion of the mollic epipedon, mostly from cultivation.

Order Mollisols are very dark-colored, naturally very fertile soils of grasslands.

Suborder Aquolls are the wet Mollisols. These soils commonly develop in low areas where water collects and stands, but some are on broad flats or on seepy hillsides. Most of the soils have had a vegetation of grasses, sedges, and forbs, but a few also have had forest vegetation. In the United States, Aquolls are most extensive in glaciated areas of the Midwestern States where the drift or loesswas calcareous.

Suborder Udolls are the more or less freely drained Mollisols of humid climates. They formed mainly in late-Pleistocene or Holocene deposits or on surfaces of comparable ages. In the United States, their vegetation at the time of settlement was dominantly a tall grass prairie, but some of the soils on Pleistocene surfaces appear to have supported at some time a boreal forest that was supplanted by grasses several thousand years ago. Where slopes are not too steep, nearly all of these soils are cultivated. Maize (corn) and soybeans are the major crops. Many Udolls have undergone significant erosion ...

Suborder Ustolls are the more or less freely drained Mollisols of subhumid to semiarid climates. Rainfall occurs mainly during a growing season, often in heavy showers, but is erratic. Drought is frequent and may be severe. During a drought, soil blowing becomes a problem. In nonirrigated areas, the low supply of moisture usually limits crop yields. Most of the Ustolls on the Great Plains in the United States had grass vegetation when the country was settled. In drier areas they supported mostly short grasses, and in more humid areas they supported mixtures of short and tall grasses.

Order Spodosols are acid soils with low fertility and accumulations of organic matter and iron and aluminum oxides in the subsoil.

Suborder Orthods are the relatively freely drained Spodosols that have a spodic (accumulation of translocated organic matter in complex with aluminum and also commonly iron) subsoil horizon. They formed predominantly in coarse, acid Pleistocene or Holocene deposits under mostly coniferous forest vegetation.

Order Vertisols are very clayey soils that shrink and crack when dry and expand when wet.

Suborder Aquerts are the wet Vertisols. They are saturated to the surface by ground water for a long enough period during the year to become devoid of oxygen (aquic conditions). However, they also are dry for periods long enough during the year for cracks to open. These soils are typically in low areas, such as glacial lake plains, flood plains, stream terraces, and depressions.

Suborder Uderts are the Vertisols of humid areas with seasonally well-distributed rainfall. These soils have cracks that open and close, depending upon the amount of precipitation. In some years the cracks may not open completely. The Uderts in the United States occur on gentle slopes and are derived dominantly from marine shales, chalks, marls, and alluvium. At one time, many of these soils supported native grasses while some supported hardwood or pine forest. Currently, these soils are used for pasture, row crops, or woodland.