USGS-NPS VEGETATION MAPPING PROGRAM

Voyageurs National Park, Minnesota

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EXECUTIVE SUMMARY

The Biological Resources Division of the U.S. Geological Survey (USGS) is cooperating with the Inventory and Monitoring Program of the National Park Service to classify, describe, and map vegetation for 250 National Parks. The Upper Midwest Environmental Sciences Center (UMESC) in La Crosse, Wisconsin, the Midwest Regional Office of The Nature Conservancy (TNC), and the Association for Biodiversity Information have completed mapping and classifying the existing vegetation in Voyageurs National Park and environs. The UMESC provided project coordination, photo interpretation of the aerial photographs and subsequent automation, accuracy assessment analysis, and final product compilation. Staff at the Midwest Resource Office of TNC and the Minnesota County Biological Survey of the Minnesota Department of Natural Resources conducted vegetation classification, including collection of data in the field and subsequent analysis. The Center for Biological Informatics provided oversight to the project. Staff at Voyageurs National Park organized the acquisition of the aerial photographs, provided logistical and equipment support, and provided housing and personnel for field work. This report presents the work conducted at Voyageurs National Park in northern Minnesota between 1996 and 1998.

Voyageurs National Park contains a high diversity of vegetation types typical of the southern boreal and Laurentain mixed conifer-hardwood regions. The U.S. National Vegetation Classification (USNVC) provided the standards for describing the vegetation types. The USNVC is a vegetation-based system that emphasizes natural and existing vegetation. 191 plots were collected throughout the project area, resulting in 50 community types (associations of the USNVC). The types were linked to map units, which are representations of the types to the extent that can be discerned on the aerial photographs. Sixty-seven map units, including land use/land cover and park specific categories, were used to map 156,886 hectares (387,674 acres) of Voyageurs National Park and environs, including a portion of Canada. Color infrared film at a scale of 1:15,840 provided the imagery. The interpreted photos were manually transferred to orthophoto quadrangle maps (1:12,000-scale), and subsequently automated using ArcInfo. 32,841 polygons were delineated; nearly 53% of the polygons were forest types. The greatest number of hectares (h) mapped was the Quaking Aspen-Paper Birch Forest (>21,500 h) and the largest polygons mapped (average size 30 h) were Black Spruce Bogs. The Natural Heritage Network and TNC consider a number of vegetation types at Voyageurs National Park to be globally rare. Two types are listed as Vulnerable or Apparently Secure (G3G4), the Northern Sedge Poor Fen and the White Pine / Mountain Maple Mesic Forest. The potentially rarest type, White Cedar - Yellow Birch Forest, is present in the park, but its global taxonomic status is unresolved (G2Q). 1,251 field data points were used to test the thematic accuracy of the map. Overall thematic map accuracy was assessed at 82.4%.

Products developed for the Voyageurs National Park Vegetation Mapping Project include the following:

- This final report, including methodologies, descriptions of vegetation types, vegetation key, map accuracy assessment results and contingency table, and mapping convention report and photo interpretation visual key;
- Spatial database coverages of the vegetation map, observation points, vegetation field plots, accuracy assessment sites, flight line index, and other supportive GIS data;
- Digital data files and hard copy data sheets of field work including observation points, vegetation field plots, and accuracy assessment sites;
- Aerial photographs of the project area (1 transparency set and 2 contact print sets) and their corresponding interpreted overlays;
- Representative ground photos for each vegetation type;
- Graphics of all spatial database coverages, and map composition of the vegetation map;

- Federal Geographic Data Committee compliant metadata for all vegetation spatial database coverages and field work data, and;
- CD-ROM containing reports, metadata, keys, classification lists, fieldwork data, spatial data, map composition, graphics, and ground photos.

1. INTRODUCTION

1.1 Background

The objective of the U.S. Geological Survey - National Park Service Vegetation Mapping Program is to classify, describe, and map vegetation communities for most of the park units within the National Park Service (NPS). The program was created in response to the NPS Natural Resources Inventory and Monitoring Guidelines issued in 1992. Products to each park include digital files of the vegetation map and field data, keys and descriptions to the vegetation communities (associations), reports, metadata, map accuracy verification summaries, and aerial photographs. Inter-agency teams work in each park following standardized mapping and field sampling protocols. The teams develop products and vegetation classification standards documenting the various vegetation types found in a given park.

The use of a standard national vegetation classification system and mapping protocol facilitate effective resource stewardship by ensuring compatibility and widespread use of the information throughout the NPS as well as by other federal and state agencies. These vegetation maps and associated information support a wide variety of resource assessment, park management, and planning needs, and provide a structure for framing and answering critical scientific questions about vegetation communities and their relationship to environmental processes across the landscape.

The U.S. National Vegetation Classification (USNVC) is used for park mapping. The classification:

- Is vegetation based;
- Uses a systematic approach to classify a continuum;
- Emphasizes natural and existing vegetation;
- Uses a combined physiognomic-floristic hierarchy;
- Identifies vegetation units based on both qualitative and quantitative data;
- Is appropriate for mapping at multiple scales.

The USNVC has primarily been developed and implemented by The Nature Conservancy (TNC) and the network of Natural Heritage Programs over the past twenty years (Grossman et al. 1998). Additional support has come from federal agencies, the Federal Geographic Data Committee (FGDC), and the Ecological Society of America. Refinements to the classification occur in the process of application, leading to ongoing proposed revisions that are reviewed both locally and nationally. TNC has made available a 2-volume publication presenting the standardized classification, providing a thorough introduction to the classification, its structure, and the list of vegetation types found across the United States as of April 1997 (Grossman et al. 1998). This publication can be found on the Internet at: http://www.conserveonline.org/2001/03/p/en/vol1.pdf. The Association for Biodiversity Information (ABI) has since superceded Volume II of the publication (the classification listing), providing regular updates to ecological communities in the United States and Canada. This online database server, NatureServe®, can be found on the Internet at: http://www.natureserve.org/publications/icec.

Further information about the USGS-NPS Vegetation Mapping Program, including examples of completed parks, may be viewed at the Program's web site: http://biology.usgs.gov/npsveg.

1.2 Voyageurs National Park

Voyageurs National Park was authorized in 1971 and established in 1975. The park extends for over 50 km along the Canadian - United States international border, from 29 km east of International Falls to the western edge of the Boundary Waters Canoe Area (BWCA) in the Superior National Forest (Figure 1). It covers 88,244 h (218,055 acres), of which 61.6% (54,336 h, 134,266 acres) is land, the rest open

lakes and ponds. Four large lakes comprise the majority of the water area. The climate is mid-continental, with a mean annual temperature of 1.4 °C, extremes of -40 and 36 °C and a mean annual precipitation of 63 cm per year (Kurmis et al. 1986). The landscape is rugged Canadian Shield terrain, consisting of Early Precambrian granite (more common in the southern part of the park), biotite schist (more common in the north), and migmatite (interlayered granite and biotite). A greenstone belt outcrop occurs in a limited region of the northwestern part of the park. Mafic dikes occur in localized areas. Prolonged erosion and glacial scouring during the Pleistocene have produced the current surficial geology features, which include sandy loam tills, lacustrine deposits (particularly on the western edge from glacial Lake Agassiz, but also in localized lowlands and bedrock depressions), and localized outwash deposits of sand and gravel (Okajangas and Matsch 1982).

Figure 1. Location of Voyageurs National Park in Northern Minnesota

Soils formed in the glacial deposits range from thin, loamy, and well drained, often in raised areas with bedrock outcrops, to thick, clayey, and poorly drained low-lying areas (Kurmis *et al.* 1986). The topography of the area is a complex pattern of low ridges and valleys, with a maximum relief of 90 m (Johnston and Naiman 1990), but more typically 20 to 30 m. All of Voyageurs National Park falls in one ecological land unit at the subsection level, the Border Lakes subsection (212La of Keys et al. 1995).

Prior to settlement and logging, which began around 1875 and ended in the early 1970s (cutting almost all of the park forests in the process), the vegetation consisted of jack pine forests with rocky outcrops, white and red pine forests, spruce-fir and aspen forests, black spruce-tamarack bogs and swamps, fens, wet meadows, marshes, and aquatics (Marschner 1974, Kurmis et al. 1986). Periodic fires both before and after settlement favored the fire-dependent pines, as well as the aspen-birch forests. Based on analyses from the adjacent BWCA (Heinselman 1996), fires could sweep through thousands of acres at a time. Heinselman's work indicated that jack pine stands in the BWCA had high-intensity catastrophic burns every 50-100 years, whereas red pine and white pine generally had more frequent low-intensity burns every 30-40 years, but less frequent high-intensity burns every 200 years or so. Windstorms, spruce-budworm disease, herbivores, and beaver activity are other disturbance factors acting in the park (Johnston and Naiman 1990, Crowley 1995).

2. METHODS

2.1 Planning

In May 1996, personnel from Voyageurs National Park, U.S. Geological Survey (USGS) Center for Biological Informatics (CBI), USGS Upper Midwest Environmental Sciences Center (UMESC), The Nature Conservancy (TNC, Midwest Office), and Minnesota Department of Natural Resources (Ecological Services) held a planning meeting at Voyageurs National Park headquarters in International Falls, Minnesota to organize the mapping project. Specific goals of the meeting were to review existing data, determine boundaries for the project, discuss logistics and protocols, and assign tasks. Among the topics and tasks discussed were use of existing data, development of the classification and sampling strategy, data analysis, photo interpretation and cartography, and accuracy assessment. Specific responsibilities and final products were assigned.

UMESC responsibilities and products:

- Facilitate project activities;
- Perform field reconnaissance to develop map unit and vegetation classifications, and to verify vegetation and land use/land cover appearances on the aerial photographs;
- Develop map units that link to the USNVC and other classification systems;
- Assist TNC with information regarding the distribution and occurrence of vegetation types within the park;
- Interpret and delineate vegetation and land use types using aerial photographs;
- Transfer and automate interpreted information to produce a digital spatial database (in various formats) and hard copy vegetation maps;
- Produce spatial coverages of observation point, vegetation field plot, and accuracy assessment site locations;
- Provide accuracy assessment analysis and report results;
- Provide a final report describing all aspects of the project;
- Provide a photo interpretation mapping convention report and visual key;
- Document FGDC compliant metadata for all vegetation data, and;
- Provide a CD-ROM containing reports, metadata, keys, classification lists, fieldwork data, spatial data, map composition, graphics, and ground photos.

TNC responsibilities and products:

- Develop a preliminary and final vegetation classification for the study area based on the USNVC;
- Provide guidance to the photo interpreters regarding the ecology and floristic compositions of the vegetation types;
- Design a sampling strategy to collect vegetation data;
- Sample representative stands for all vegetation communities;
- Provide vegetation descriptions and keys to vegetation communities;
- Field test final classification, descriptions, and keys during accuracy assessment;
- Collect accuracy assessment data;
- Provide a PLOTS database of vegetation field plot and accuracy assessment data, and;
- Provide documentation on field and analyses methodology and results.

Voyageurs National Park was one of the pilot/prototype parks, so extended vegetation work was conducted to apply, test, and refine the methods. Staff at the UMESC in La Crosse, Wisconsin performed photo interpretation of the aerial photographs and subsequent automation. (Staff at the USGS Mid-continent Ecological Science Center in Ft. Collins, Colorado provided automation on a small northern section of the vegetation spatial database.) Staff at the Midwest Regional Office of TNC and its affiliate,

the Minnesota County Biological Survey of the Minnesota Department of Natural Resources conducted vegetation classification, including collection of data in the field and subsequent analyses. CBI provided oversight to the project. This report presents the work conducted at Voyageurs National Park between 1996 and 1998.

2.2 Aerial Photograph Acquisition

Voyageurs National Park staff contracted KBM, INC (1604 S. Washington St., Grand Forks, ND 58201-6334) to collect aerial photographs of the park and environs (Figure 2). A portion of the northern one-third of project was collected on September 27, 1995. The remaining area was collected in 1996 (September 13, 14, and October 3). The photos were taken at a flight altitude of 7,920 feet above sea level with a Jena Link 15/2323 camera using Kodak Aerochrome Infrared 2443 film. The photo mission was designed to take photos with about 30% side lap (between each flight line) and 60% overlap (along each flight line). The scale of the color infrared (CIR) 9 x 9-inch transparencies is 1:15840 (approximately 4 inches to one mile). A total of 782 photos along 20 flight lines were collected. The photo mission covered the entire project area, which includes the entire park and environs (Figures 3 and 4). Only 509 of these photos were necessary to map the defined project area. An existing set of CIR photo prints, taken in the fall of 1988 at a scale of 1:12,000, were used as collateral information (see section 2.7 Photo Interpretation).

Figure 2. Example of an aerial photograph for the Voyageurs National Park Vegetation Mapping Project (example is not to scale)

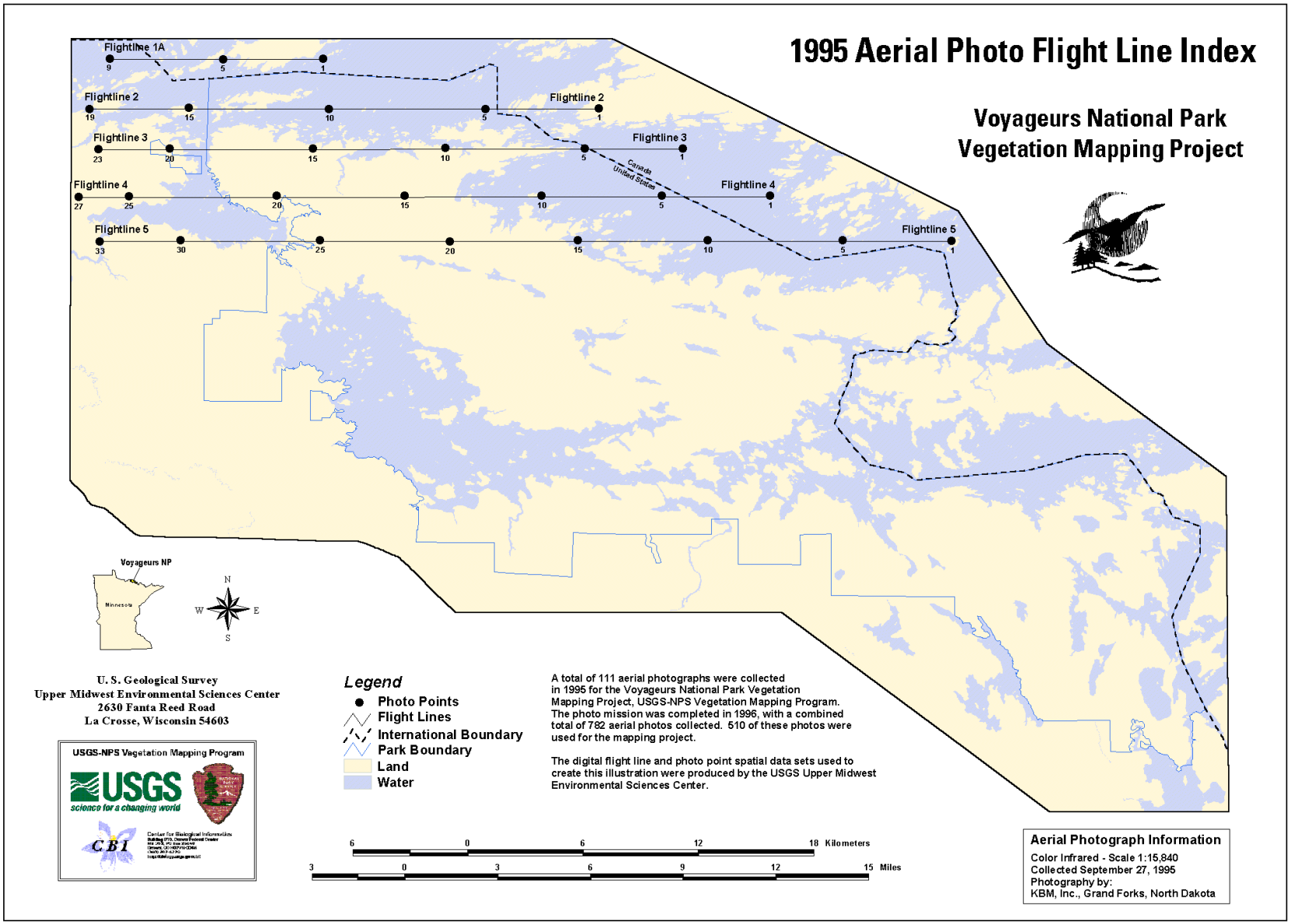

Figure 3. 1995 Aerial Photo Flight Line Index.

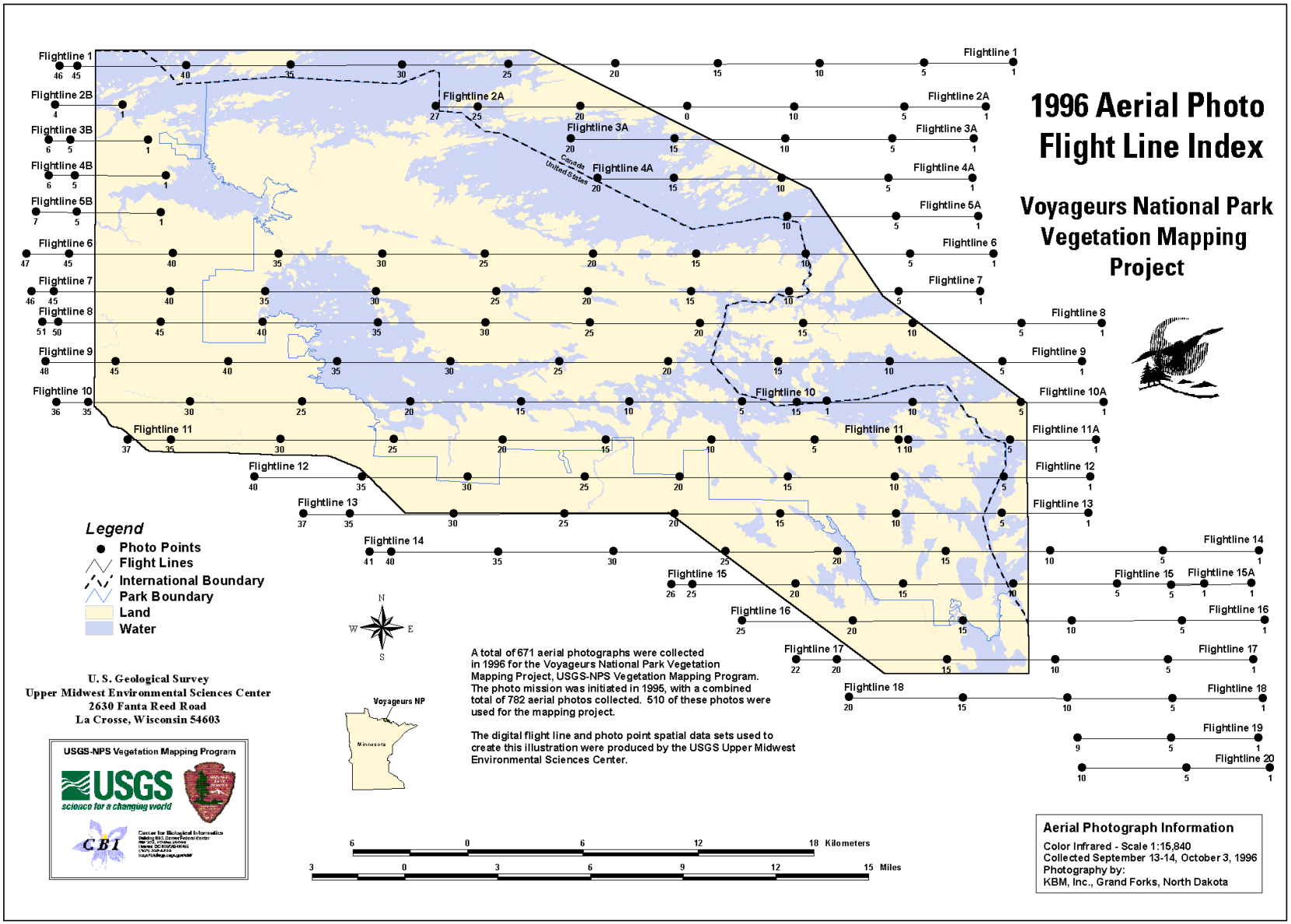

Figure 4. 1996 Aerial Photo Flight Line Index

2.3 Vegetation Classification and Preliminary Classification List

The USNVC, developed by TNC and the network of state Natural Heritage Programs, was used for classifying the vegetation for the Voyageurs National Park Vegetation Mapping Project. The classification is a hierarchical system with physiognomic features at the highest levels of the hierarchy and floristic features at the lower levels. The physiognomic units have a broad geographic perspective and the floristic units have local and site-specific perspective (Grossman et al. 1994, 1998).

The national classification includes most existing vegetation, whether natural or cultural, but TNC has focused attention on natural vegetation types. "Natural vegetation" as defined in Grossman et al. (1994) includes types that "occur spontaneously without regular management, maintenance, or planting and have a strong component of native species". "Cultural" vegetation includes planted/cultivated vegetation types such as orchards, pastures, and vineyards.

The physiognomic-floristic classification includes all upland terrestrial vegetation and all wetland vegetation with rooted vascular plants. The hierarchy has seven levels, with five physiognomic levels and two floristic levels (Table 1). The basic unit of the physiognomic portion of the classification is the "formation", a type defined by dominance of a given growth form in the uppermost stratum and characteristics of the environment (e.g., cold-deciduous alluvial forests). The physiognomic portion of the classification is based upon the UNESCO world physiognomic classification of vegetation, which was modified to provide greater consistency at all hierarchical levels and to include additional types (Drake and Faber-Langendoen 1997).

The floristic levels include alliances and associations. The alliance is a physiognomically uniform group of plant associations that share dominant or diagnostic species, usually found in the uppermost strata of the vegetation. For forested types, the alliance is roughly equivalent to the "cover type" of the Society of American Foresters. Alliances also include non-forested types.

The association is the lowest level in the national classification. The association is defined as "a plant community of definite floristic composition, uniform habitat conditions, and uniform physiognomy" (see Flahault and Schroter 1910 in Moravec 1993). Most schools of floristic classification have used this concept.

Table 1. The USNVC's Physiognomic-floristic Hierarchy for Terrestrial Vegetation (from Grossman et al. 1998).

Level	Primary Basis For Classification	Example
Class	Growth form and structure of vegetation	Woodland
Subclass	Growth form characteristics, e.g., leaf phenology	Deciduous Woodland
Group	Leaf types, corresponding to climate	Cold-deciduous Woodland
Subgroup	Relative human impact (natural/semi-natural or cultural)	Natural/Semi-natural
Formation	Additional physiognomic and environmental factors, including hydrology	Temporarily Flooded Cold-deciduous Woodland
Alliance	Dominant/diagnostic species of uppermost or dominant stratum	Populus deltoides Temporarily Flooded Woodland Alliance
Association	Additional dominant/diagnostic species from any strata	*Populus deltoides – (Salix amygdaloides) / Salix exigua* Woodland

A preliminary list of vegetation types (associations and alliances) from Faber-Langendoen et al. (1996, Midwest portion of USNVC) was generated for the park in May of 1996, based on a variety of sources. This list was part of early drafts of the USNVC (Grossman et al. 1998). These drafts were reviewed by many ecologists, including those of the Minnesota County Biological Survey and the Natural Heritage Program. In addition, recent publications on vegetation types in northwestern Ontario, such as those by

Sims et al. (1989) and Harris et al. (1996), were also consulted and used to refine the list. This early USNVC list served as a starting point for plot sampling and field reconnaissance. The USNVC database contains a crosswalk to the Minnesota state classification to ensure compatibility between the two systems.

2.4 Reconnaissance and Verification for Mapping and Classification

The preliminary classification was field tested during the summer and fall of 1996. A combined team of aerial photo interpreters and ecologists collected observation point data on the vegetation communities they encountered while in the field (Figure 5**,** Appendix A). The data helped clarify the nature of the classification units and their diagnostic aerial photo signatures.

Additional aerial photo "ground truth" fieldwork was performed throughout the 1996 field season by the photo interpretation team to learn, test, and verify photo signatures. Efforts were concentrated in the northern one-third of the project area for which a set of photographs had already been acquired. Ecologists intermittently assisted to assure correct field calls and to verify additional vegetation types as they were encountered.

By the end of the 1996 field season, mapping protocols were sufficiently stabilized to permit the aerial photo interpretation team to begin delineating polygons for the northern one-third of the project area. During the 1997 field season, "ground truth" field activities continued, focusing on the southern two-thirds of the project area with an emphasis on photo signatures not commonly observed the previous year. Throughout this field process, map unit classes were developed, and a fuller understanding of their linkage to vegetation types was strengthened.

Figure 5. Reconnaisance through a Black Spruce / Leatherleaf Semi-treed Bog

2.5 Creation of Map Units

The relationship between vegetation mapping and classification of vegetation types is extremely complex. Timing of the photo mission, type of film (e.g. true color or color infrared), scale, and resolution all contribute to how accurately vegetation can be mapped. Having two sets of aerial photographs (fall 1995/1996 set and fall 1988 set) was helpful in developing vegetation map units as each set supplied different information regarding the appearance of USNVC vegetation types (alliances and associations). However, even with two sets of photographs, not every vegetation type verified in the field could be clearly discerned on the aerial photographs.

Developing map units compatible with the vegetation types found within the project area was developed jointly between the photo interpretation and ecologist teams during the reconnaissance and subsequent "ground-truth" field trips, with further refinement following fieldwork. Field days were spent discussing structural, floristic, and habitat characteristics of the vegetation types encountered and comparing the types to their appearances on the photos. Through this process, decisions were made as to how to map the vegetation types. When vegetation communities were difficult to discern on the photographs, it became necessary to aggregate vegetation communities into single map units. For example, map unit Aspen-Birch Forest (AB) is compatible to the USNVC Aspen - Birch Forest Alliance as it contains two associations within that alliance: Aspen - Birch Boreal Conifer Forest and Aspen - Birch - Red Maple Forest. These 2 associations appear similar on the aerial photographs, with no discriminating features to allow for mapping separately. Further, the Aspen - Birch - Red Maple Forest is not common in the project area. Other map unit aggregates are explained in section 3.4 Map Units.

Subsequent to fieldwork, a list of map units representing vegetation types was developed with careful attention to each map unit's relationship to the classification. Once the photo interpretation began, new questions surfaced regarding the map units, so discussions were continued between the two teams to insure a clear understanding of the relationships between map units and the vegetation types. Once the relationships stabilized, a classification matrix was developed that illustrates the relationship between the map units and the vegetation associations (Appendix B).

Additional map units were derived to map land use and land cover features not described by the USNVC, such as populated areas, roads, agricultural lands, quarries, and large open water bodies that are <10% vegetated. To map these features, a land use and land cover classification system developed by Anderson et al. (1976) was used (to Level II). A few more map units were developed to map park specific situations such as small islands less than the minimum mapping unit of .5 h, and small natural ponds (open water <10% vegetated).

Map units were reviewed by resource management staff at Voyageurs National Park and offered additional mapping criteria based on resource management needs.

In addition to map units, a set of modifiers was derived to provide additional information (when applicable) about the physiognomic structure of the vegetation type being mapped.

2.6 Vegetation Sampling and Analysis for Classification Development

In general, the vegetation field sampling methods used for developing the classification followed the methodology outlined by the USGS-BRD/NPS Vegetation Mapping Program (Grossman et al. 1994). Voyageurs National Park is a large-sized park (100 - 2,500 km^2) based on land area (543 km^2). In addition, the mapping project included the environs around the park, making the total area mapped about 1,569 km^2. However, the landscape is not too complex, and most of the park and environs fall in one ecological subsection (Border Lakes: 212La), as reported by the ECOMAP ecological land classification (Keys et al. 1995). Thus, although a gradsect sampling approach is recommended based on size, it was

used in a modified form. The park was stratified into three areas: the western peatland area (Rat Root River peatland), which falls mostly outside the park boundaries, the northern unit, where the bedrock is primarily biotite schist (metasedimentary rocks) with local areas of greenstone, and a southern unit, where the bedrock is primarily granite (the Vermillion granitic complex) (Okajangas and Matsch 1982). In the first year of reconnaissance and sampling (1996), the first two areas were emphasized. In the second and third years (1997 and 1998), the third area was emphasized.

Plot sampling was generally limited to an average of 3 plots per type. Less well-understood types were sampled more extensively (Figure 6). These plots were spread across the park as much as possible. Some types were restricted to the Rat Root River peatland complex. All plots for those types were located there. For the rest, 1-2 plots were taken in both the northern and southern units. Special emphasis was given to the greenstone outcrop areas. 191 plots were collected as part of this project (Figure 7). Additional plots were available from a study by Kurmis et al. (1986) and Minnesota Natural Heritage Program surveys in the area.

Plot sizes ranged from 20 x 20 m for forests and woodlands to 10 x 10 m for shrublands, herbaceous, and nonvascular vegetation. Plots were placed subjectively in the most representative part of each stand of vegetation. The vegetation was visually divided into strata, and height and cover abundance of each stratum was estimated. Cover of dominant life forms was also estimated to match methods used by the Minnesota Natural Heritage Program survey methods (e.g. total cover of evergreen trees or shrubs was recorded separately from cover of deciduous trees or shrubs (Norm Aaseng, personal communication, 1996). All the species of each stratum were listed (including mosses and lichens) and percent cover estimated using the Braun-Blanquet cover scale. Additional species within the vegetation unit or polygon that occurred outside of sampled plots (generally within 2 m of the plot border) were listed separately. Species that were not identifiable in the field were collected for later identification. In addition to floristic information, the following environmental information was recorded on field forms: surficial geology, hydrologic (flooding) regime, soil drainage regime, soil texture, slope, aspect, topographic position, and evidence of disturbance. X-Y coordinates of each plot were recorded in Universal Transverse Mercator (UTM) projection (Zone 15) using a Rockwell Precision Lightweight GPS Receiver (PLGR) and, on occasion, a Trimble GPS unit). Other locational information was also recorded. A provisional name for the vegetation type was assigned to the plot.

Figure 6. Conducting a vegetation plot within a rocky woodland.

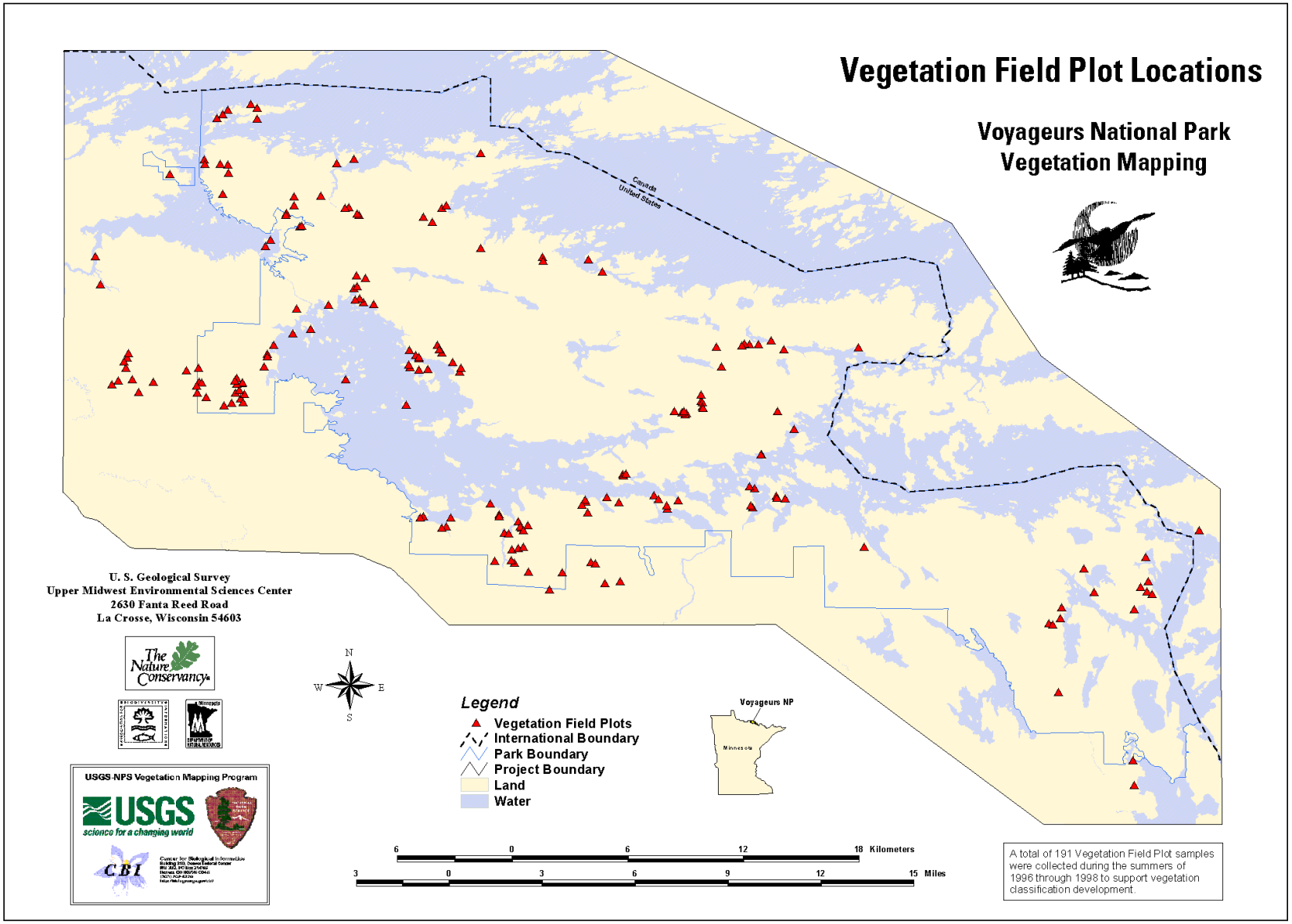

Figure 7. Location of vegetation plots collected for the Voyageurs National Park Vegetation Mapping Project

Vegetation plot data were entered into the Minnesota Natural Heritage Program's plot database. Species were assigned standardized codes and names based on the PLANTS database (USDA, NRCS 1999). These data were transferred to the PLOTS database developed by the Nature Conservancy (TNC 1997) for final inclusion in this report. For the vegetation analysis, the data were analyzed using the PC-ORD Multivariate Analysis package (McCune and Mefford 1997). The data were analyzed in a series of runs, partitioning the data into smaller sets based on clusters found in the larger data sets, until sufficient resolution was achieved. Multivariate analysis was done using both Non-metric Multidimensional Scaling or NMS (Clarke 1993) and Cluster Analysis. A Bray-Curtis ordination was used as a starting point for the NMS and Ward's Method was used in the Cluster Analysis. These were then reviewed and assessed for perceived environmental gradients (e.g. moisture gradients, peat depth, soil depth, etc.). Indicator Species Analysis (Dufrene and Legendre 1997) was used to identify indicator species and to assess the reassignment of plots into different cluster analysis groups.

These groups were compared with the USNVC (Faber-Langendoen et al. 1996, Grossman et al. 1998), as well as to northwestern Ontario types (Sims et al. 1989 and 1997, Harris et al. 1996). Care was taken not to over-emphasize local variations found at Voyageurs compared to more extensive information compiled at the state or regional level. Nevertheless, several types in the USNVC were revised based on these analyses. Plot summaries were produced for each type.

2.7 Photo Interpretation

Preparation of the aerial photographs for interpretation follows procedures of Owens and Hop (1995). The 1995 and 1996 CIR film transparencies were cut from rolls and covered with clear acetate overlays. The overlays were registered to the transparency photos and subsequently labeled with flight line and photo numbers.

Field reconnaissance was performed to learn, test, and verify photo signatures of vegetation types and other non-vegetated features (land use/land cover) and to establish a map classification. Once mapping protocols were established, photo interpretation and mapping proceeded.

Photo interpretation was performed using the 1995 and 1996 photo transparencies. Ground features were interpreted, and subsequently were delineated and labeled with map unit codes onto the photo overlays using a Bausch and Lomb Zoom 240 stereoscope over a light table. Each transparency photo was viewed with its matching stereo pair (adjacent photo) so images could be seen in 3-dimensions. To minimize edge distortion, interpretation was focused towards the center of each aerial photograph. Texture, height, color, pattern, life form, and position in the landscape were all used in the decision making process of delineating polygons and assigning map unit codes. In addition to photo signature characteristics, the photo interpreter's knowledge of the environmental distribution of the types was used to help confirm the identity of the signatures. A standard minimum mapping unit of 0.5 h was applied. Small upland islands were mapped to 0.1 h. 509 aerial photographs of the 1995/1996 set were interpreted for the project.

With mapping vegetation types, a polygon is delineated to define a particular vegetation type. The polygon is attributed with a map unit code that represents the vegetation type. Conventionally, a polygon is not sub-divided because of physiognomic structural changes with the vegetation (e.g. density, height). However, extensive structural changes (e.g. large blowdown areas) within a map unit polygon were delineated separately. To attribute the physiognomic structure of the vegetation, a systematic string of modifier codes (see Appendix F for conventions) were added to map unit code (Table 2, e.g. DMX-2B, BA-1A4, WRPA-1A2M). Physiognomic modifiers are added (when applicable) to all vegetation map units.

During the onset of mapping, other maps were used to gain familiarity with vegetation characteristics. A map of Kabetogama Lake [*1988 Vegetation of the Kabetogama Peninsula, Minnesota. Unpublished map (1:24,000), Natural Resources Research Institute, Duluth, Minnesota. Funded by National Science Foundation Grant DEB-9119614]* and National Wetlands Inventory 7.5-minute quadrangle maps (U.S. Fish and Wildlife Service, St. Petersburg, Florida) were especially useful during the initial stages of photo interpretation.

Throughout the entire interpretation process, October 1988 CIR photographs were also viewed to better determine vegetation types. The 1988 photos, because they effectively captured fall colors in leaf canopies, were very helpful in revealing various distinctions not apparent on the 1995 and 1996 photographs. The primary characteristic that differed was that of color. Where changes in the vegetation occurred between the two sets of photographs, only characteristics on the recent set were used to determine the types.

For more details on photo interpretation and how each map unit was interpreted, see Appendix F.

Table 2. Physiognomic modifiers assigned to polygons during photo interpretation.

COVERAGE DENSITY	1 2 3	Closed Canopy/Continuous (60-100% cover) Open Canopy/Discontinuous (25-60% cover) Dispersed-Sparse Canopy (10-25% cover)
COVERAGE PATTERN	A B C D	Evenly Dispersed Clumped/Bunched Gradational/Transitional Regularly Alternating
HEIGHT	1 2 3 4 5 6	30-50 meters (98-162 feet) 20-30 meters (65-98 feet) 12-20 meters (40-65 feet) 5-12 meters (16-40 feet) 0.5-5 meters (1.5-16 feet) <0.5 meters (<1.5 feet)
DOMINANCE/CO-DOMINANCE	D E M	Deciduous 60-75% dominance of existing tree coverage; evergreen 25-40% Evergreen 60-75% dominance of existing tree coverage, deciduous 25-40% Deciduous/Evergreen 40-60- % co-dominance of existing tree coverage

2.8 Transfer and Automation of Photo Interpreted Data

To geo-reference the photo interpreted data, zoom transfer scopes were used to manually transfer the interpreted polygons onto drafting film over base maps. The transfer process removes much of the aerial photograph's inherent distortion and ties the interpreted data to real-world coordinates so it can be digitally automated. Fifty-one USGS 3.75-minute digital orthophoto quadrangles (DOQ) were used to plot hard copy (film acetate) orthophoto base maps at a scale of 1:12,000 (Figure 8). For portions of Canada not covered by DOQ maps, Ontario Basic Mapping Series (OBM, Ontario Ministry of Natural Resources) topographic paper maps at a scale of 1:20,000 were used (Figure 9). About 92% of the project area was produced with the DOQ-based maps, covering the Voyageurs National Park, all the environs within the USA, and portions of the environs within Canada.

The interpreted polygons were manually transferred to overlays that were registered to the base maps. Map unit attributes and appropriate physiognomic modifier codes were added to a second overlay. The overlays were subsequently rechecked for accuracy. Each overlay of transferred data was scanned using a large format sheet fed scanner at a resolution of 400 dots per inch. The resulting Tagged Image File Format (TIFF) images were then converted to a grid using ArcInfo (Version 7.2.1 Patch 2, Environmental Systems Research Institute, Redlands, California). For data produced with the DOQ base maps, the converted grid was projected to UTM Zone 15 using North American Datum of 1983 (NAD83). For data

produced with OBM base maps, the converted grid was projected to UTM Zone 15 using North American Datum of 1927 (NAD27) and later converted to NAD83 once all OBM-based digital coverages were produced and joined. Each individual grid was transformed to a geo-referenced boundary coverage to digitally reference the data to real-world coordinates. In ArcTools, the ArcScan utility was used to trace the referenced polygon data creating ArcInfo coverage. Each intermediate coverage was edited for errors, assigned attributes to polygons, checked against the hand-transferred overlays for line and attribute errors, and finally joined to produce a seamless spatial database coverage of the vegetation map.

The Look Up Table (LUT) was produced in spreadsheet format (dBASE IV), and then converted to an ArcInfo table using ArcInfo (Version 8.0.2). The table was merge with the spatial database coverage using a common attribute item (CODE_MOD). The LUT contains numerous items that, when linked to the coverage, offers a set of information for each polygon. The LUT includes items as follows:

(*NOTE - citations to classification systems are not necessarily complete*)

CODE_MOD	Map Unit Code with all applicable physiognomic feature modifiers
MAP_CODE	Map Unit Code - UMESC derived, project specific
MAP_DESC	Map Unit Description Name - UMESC derived, project specific
DENS_MOD	Coverage Density Modifier - numeric code-description - applies to all vegetation map units
PTRN_MOD	Coverage Pattern Modifier - alpha code-description - applies to all vegetation map units
HT_MOD	Height Modifier - numeric code-description - applies to woody terrestrial vegetation map units
DOM_MOD	Dominance/Co-dominance Modifier - alpha code-description - applies to mixed conifer/deciduous woody terrestrial vegetation map units
ASSN_NAME	Project Global Community Name - USNVC Association
ASSN_CNAME	Project Global Common Community Name - synonym name of Association
ASSN_CEGL	Community Element Global Code - Elcode link to USNVC Association
ALL_NAME	USNVC Alliance Name
ALL_CNAME	Common Alliance Name - translated common name of USNVC Alliance
ALL_KEY	Alliance Key -Code representing USNVC Alliance
NVCS_CODE	USNVC Code - to USNVC Formation level
CLASS	USNVC Formation Class - Class name (code)
SUBCLASS	USNVC Formation Subclass - Subclass name (code)
GROUP	USNVC Formation Group - Group name (code)
SUBGROUP	USNVC Formation Subgroup - Subgroup name (code)
FORMATION	USNVC Formation - Formation name (code)
ECO_GROUP	Ecological Group - groups of vegetation types sharing ecological processes (TNC Midwest Conservation Science Department, Faber-Langendoen 2000)
ECO_SUBGRP	Ecological Subgroup - subgroups of vegetation types sharing eco processes (TNC Midwest Conservation Science Department, Faber-Langendoen 2000)
MNCC	Minnesota Natural Community Classification (MN Department of Natural Resources Natural Heritage Program 1993)
NWON_FEC	NW Ontario Forest Ecosystem Classification (Ontario Ministry of Natural Resources, Sims et al. 1997)
NWON_WET	NW Ontario Wetland Ecosystem Classification (Ontario Ministry of Natural Resources, Harris et al. 1996)
LUC_II	Land Use and Land Cover Classification System (USGS, Anderson et al. 1976)
COMMENT1	General description about the map unit
COMMENT2	General comment of how the map unit relates to other map units.

In addition to LUT Items listed above, ArcInfo default items are also included (e.g. perimeter, area, and polygon identification numbers).

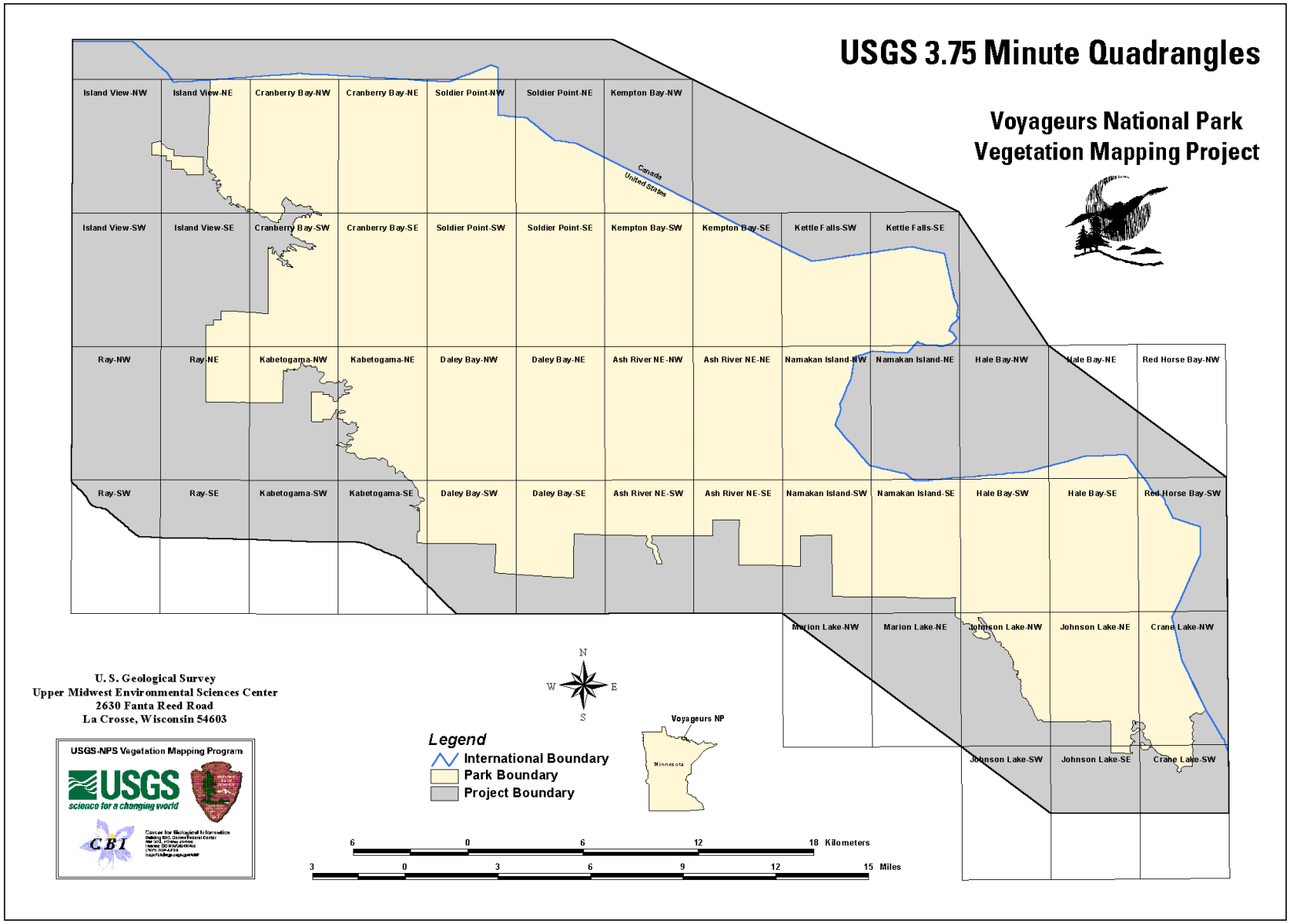

Figure 8. USGS 3.75-minute quadrangles of Voyageurs National Park and environs

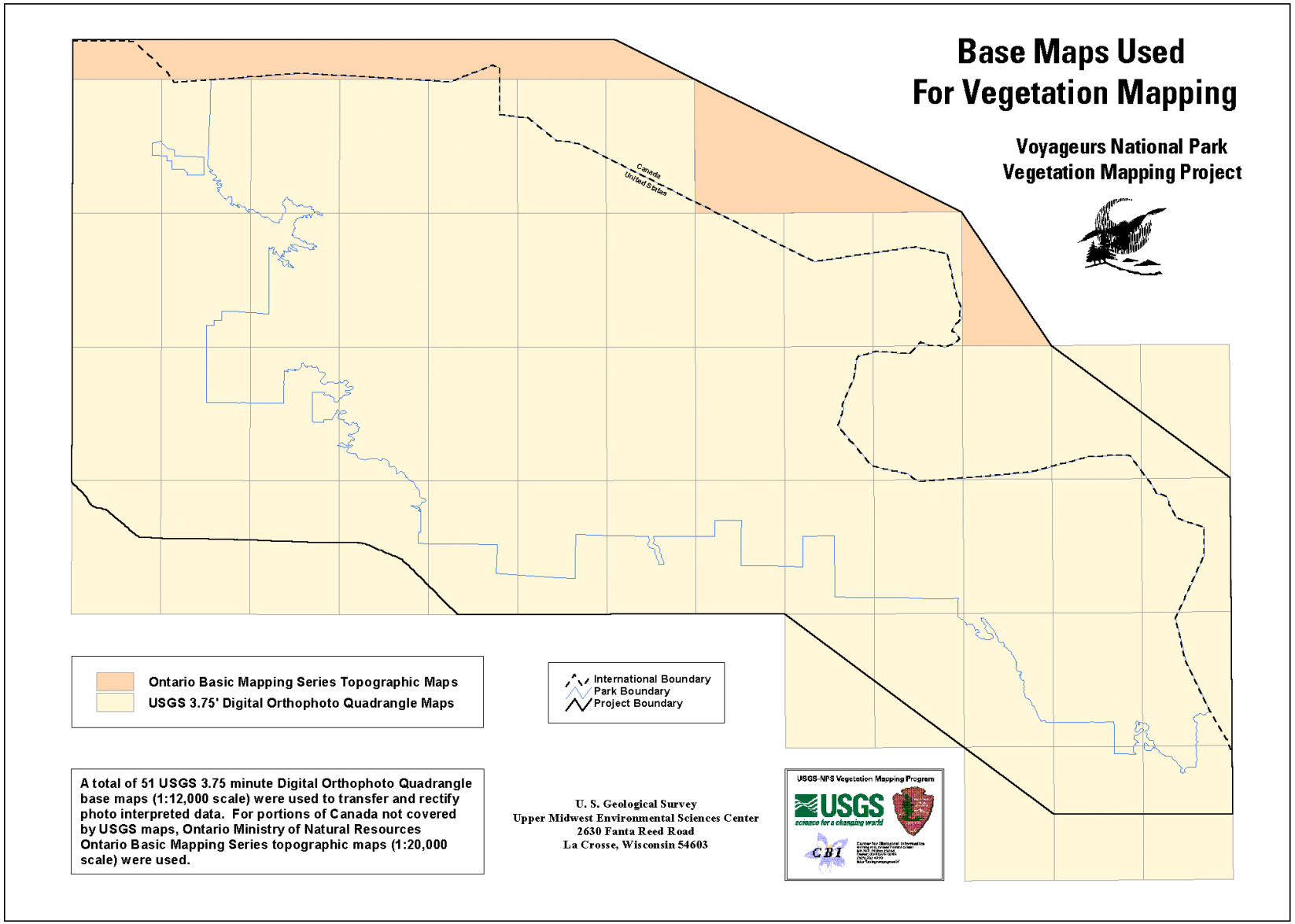

Figure 9. Distirbution of base maps used for mapping Voyageurs National Park and environs

2.9 Accuracy assessment

Once the aerial photo interpretation team had delineated polygons, an assessment of the thematic accuracy was conducted. Accuracy requirements for the USGS-NPS Vegetation Mapping Program specify 80% accuracy for each map unit. The number of sites visited per map unit depended on how common the map unit was, from 30 polygons for widespread map units to 5 for rare map units. Points were stratified as much as possible by the 3 major areas. Accuracy assessment data were collected in the field during the 1997 and 1998 field seasons.

During 1997 and early 1998 field seasons, the focus was in the northern one-third of the project area. A digital form of the polygon database was not yet available, so the accuracy assessment teams relied on copies of interpreted overlays and the aerial photos to select sites. Data for 552 accuracy assessment sites were collected using this procedure (Figure 10). The accuracy assessment team chose polygons and then hiked to the polygons to determine the community type present. The points were also distributed as evenly as possible across the northern one-third of the project area; e.g. not all of the Aspen-Birch points were taken from the same locale. Teams recorded locational information and briefly described the vegetation, noting canopy structure, dominant species by strata, and environmental features, including topographic position, slope, and aspect. The nearest vegetation communities, if known, within 50 m of the point were also recorded. Rationale for the classification type chosen was explained (Appendix C).

By the second year, much of the polygon data had been digitized, enabling the accuracy assessment team to have a computer-generated selection of sampling points. The majority of the accuracy assessment sites were selected in the bottom two-thirds of the project area. Three times the number of sites needed were generated so that points that were inaccessible or falling near polygon lines could be deleted from the selection. It was recognized that points falling on or near polygon lines could create positional errors in the field because of inherent error in the coordinate readings; PLGR units often have 10 m or more error associated with the readings. Thus, UTM coordinates selected within 10 m of a polygon boundary could actually fall within a neighboring polygon. To help avoid this potential problem, points near polygon lines were eliminated from the sampling scheme. However, some points within 10 m of polygon lines were kept so that narrow polygons would be sampled.

Hard copy 1:12,000-scale orthophoto quadrangle maps, produced from USGS 3.75-minute DOQ's, were plotted with the polygons and final accuracy assessment points overlaying the maps. Each point had a corresponding UTM coordinate that was uploaded into a PLGR GPS unit. The PLGR was used to navigate to each point. The orthophoto maps were used with the GPS unit to help navigate across the terrain. Once the sampling site was reached, the accuracy assessment team assessed the plant community within a 0.5 h radius (the minimum mapping unit) and assigned a provisional community name. Dominant species, environmental data, and rationale for classification were recorded for each site (Appendix C). Data for 736 sites were collected using this method (Figure 9).

The accuracy assessment data (1,288 points) were entered into the PLOTS database and subsequently reviewed for data entry and false errors. Incomplete data on the field sheets, including missing GPS coordinates, resulted in dropping 37 sites from further analysis. Five of these 37 sites were time factor errors. Time factor errors were due to changes in the vegetation community between the time the polygon was mapped and the accuracy assessment was conducted (i.e. exposed mud flats due to lake drawdown, or a recent beaver flooding)

The remaining 1251 points were plotted by their UTM coordinates over the spatial coverage so that all points could be viewed in relation to the vegetation map coverage. USNVC Community Element Global database codes (CEGL) for each accuracy assessment point were compared to corresponding

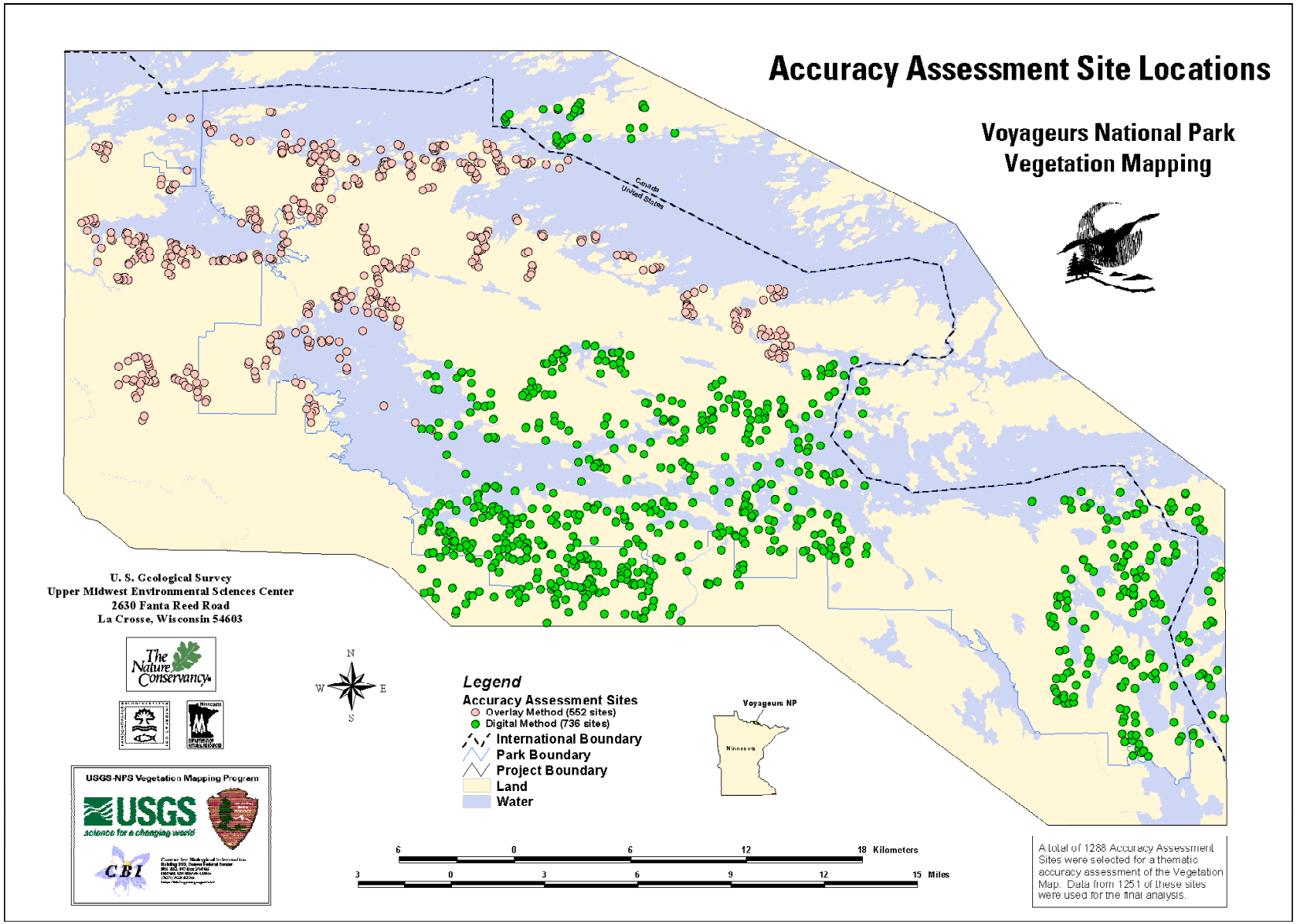

Figure 10. Locations of accuracy assessment points sampled for the Voyageurs National Park Vegetation Mapping Project

polygon map unit codes. An output file was created that listed all the accuracy assessment points and their corresponding map codes from the coverage and subsequently run through a SAS routine (SAS Institute 1996) that reported all the matches and mismatches. All mismatches were reviewed to see if there were any "false errors." Mismatches that were deemed "false errors" were corrected, resulting in either a match or a true error.

A false error is defined as a mismatch between a polygon and an accuracy assessment call if the disagreement was caused by one of the following problems:

- A GPS error;
- An accuracy assessment point occurring in a zone of transition between two types (an ecotone);
- An accuracy assessment point that was classified differently than the polygon but was clearly too small to map (an inclusion)

GPS errors occurred when the recorded coordinates were inaccurate and placed points in the wrong polygons. For example, accuracy assessment point VOYA.275, when plotted on the spatial coverage, fell within a Black Ash Forest polygon. However, the data sheet claimed the point fell within a Black Spruce / Alder Rich Swamp. Also, the point fell 2 m from a Black Spruce / Alder Rich Swamp polygon, well within the reported GPS error for this site of plus or minus 7.9 m. Thus, it was revealed that the cause of the error was inaccuracy inherent in the GPS reading (Figure 11). GPS errors were corrected after comparisons between the data sheet, the point's location, and the spatial coverage. Some GPS errors, once corrected, still resulted in a true error.

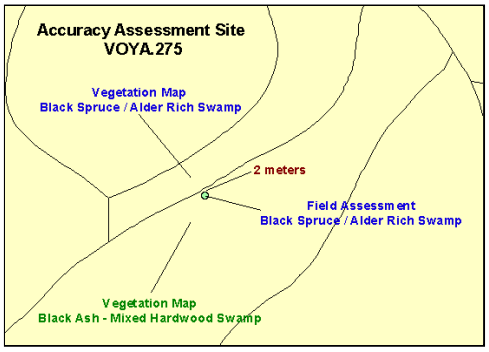

Figure 11. Example of a GPS location error

Ecotone errors occurred when sites fell in transition zones (typically near a polygon boundary) between 2 associations and the accuracy assessment crew acknowledged the presence or mixture of more than one association. When the field crew was uncertain of the correct vegetation type and one of their calls matched the polygon, the mismatch was corrected so that the polygon and accuracy assessment call matched one another.

Inclusion errors were sites where the vegetation associations recorded on the data sheets were different than the associations represented by the mapped polygons AND the accuracy assessment call was determined to represent a small area (< the minimum mapping unit) within the polygon. If it was easily determined as an area too small to map, accuracy assessment site was considered an inclusion and it was assumed that the polygon call was correct.

Map units that represented a single association were assessed together. Map units JPOM, MPHW, and OW were all considered a single association according to the classification: Northern Pin Oak - Bur Oak - (Jack Pine) Rocky Woodland Association. The 3 map units represent different phases of this association.

Three other map unit phase situations were also combined together for the assessment: JPW and JPM map units, representing evergreen and mixed phases of the Boreal Pine Rocky Woodland Association, BSL and BST map units, representing evergreen and mixed phases of Black Spruce / Labrador Tea Poor Swamp Association, and WCS and WCT map units, representing the White Cedar - (Mixed Conifer) / Alder Swamp Association.

PROC FREQ (SAS Institute 1996) was used to compare the final accuracy assessment database with the corresponding polygons. The SAS output was transferred into a contingency table, or error matrix (Appendix D). The error matrix is an array of numbers set in rows and columns which express the number of sample units (polygons) assigned to a particular category relative to the actual category as verified on the ground. The columns represent the accuracy assessment data while the rows represent the mapped polygons. Map accuracy of each category is expressed as a percentage of correctly classified polygons compared to the accuracy assessment results.

3. RESULTS AND DISCUSSION

3.1 Vegetation Classification

Voyageurs National Park contains a high diversity of vegetation communities (associations) typical of the southern boreal or Laurentain mixed conifer-hardwood region, including both upland and wetland types. The analysis of the plot data in large part corroborated the preliminary classification produced from other sources, based on sampling work at Voyageurs (Kurmis et al. 1986), from adjacent Ontario (Sims et al. 1989, Harris et al. 1996), and the Midwest classification (Faber-Langendoen et al. 1996). It also suggested some important refinements, particularly in the open bedrock and the conifer swamp types. All changes to types were integrated into the USNVC (Faber-Langendoen 2000)

A total of 50 community types are reported for Voyageurs National Park (Table 3). 191 plots were used to characterize these types. The plot data were first partitioned using ordination methods, TWINSPAN, and cluster analysis into 2 main sets, those that were primarily herbaceous wetlands (including submerged aquatics, wet meadows, and fens), and all other types (Figure 12). Within the first set, the herbaceous wetland types separated into two subsets, the deep marsh and submerged aquatic types, and the wet meadow-fen types. Within the deep marsh and submerged aquatic subsets, subsequent ordinations and cluster analysis (not shown) separated the open water types (including pondweed, open water bulrush, and wild rice marsh types), from the inland lakes water lily type and the shoreline cattail marsh type. Within the wet meadow and fen subset, the analyses separated the reed marsh from the bluejoint, sedge meadow, and dogwood-willow shrub types, and separated the sedge wet meadow from the graminoid shore fen, supporting the association distinctions made by the existing classification.

Analysis of the second category using ordinations, TWINSPAN, and cluster analysis led to 4 major subsets, from wet, low nutrient systems (bogs and fens) to primarily peatland swamps, to wet-mesic/mesic forests and dry (fire-dependent) forests (Figure 13). Each of these subsets was analyzed in turn. The first subset, the bogs and fens, ranged from more nutrient-rich shore fens (tall shrub (bog birch) shore fens, and dwarf-shrub (leatherleaf) shore fens) to nutrient-poor black spruce bogs and swamps. The black spruce bogs (and swamps) cluster together in the ordination, with only the black spruce/labrador tea type clearly distinguishable. However, a subsequent analysis (not shown) separated the raised black spruce bog in the large peatland complex (both forest and woodland physiognomy) from black spruce/labrador tea in confined basins. Intermediate between the shore fens and the black spruce bogs are the dwarf-shrub/graminoid poor fens, the tamarack scrub fens, and the leatherleaf bogs (with and without a sparse conifer layer).

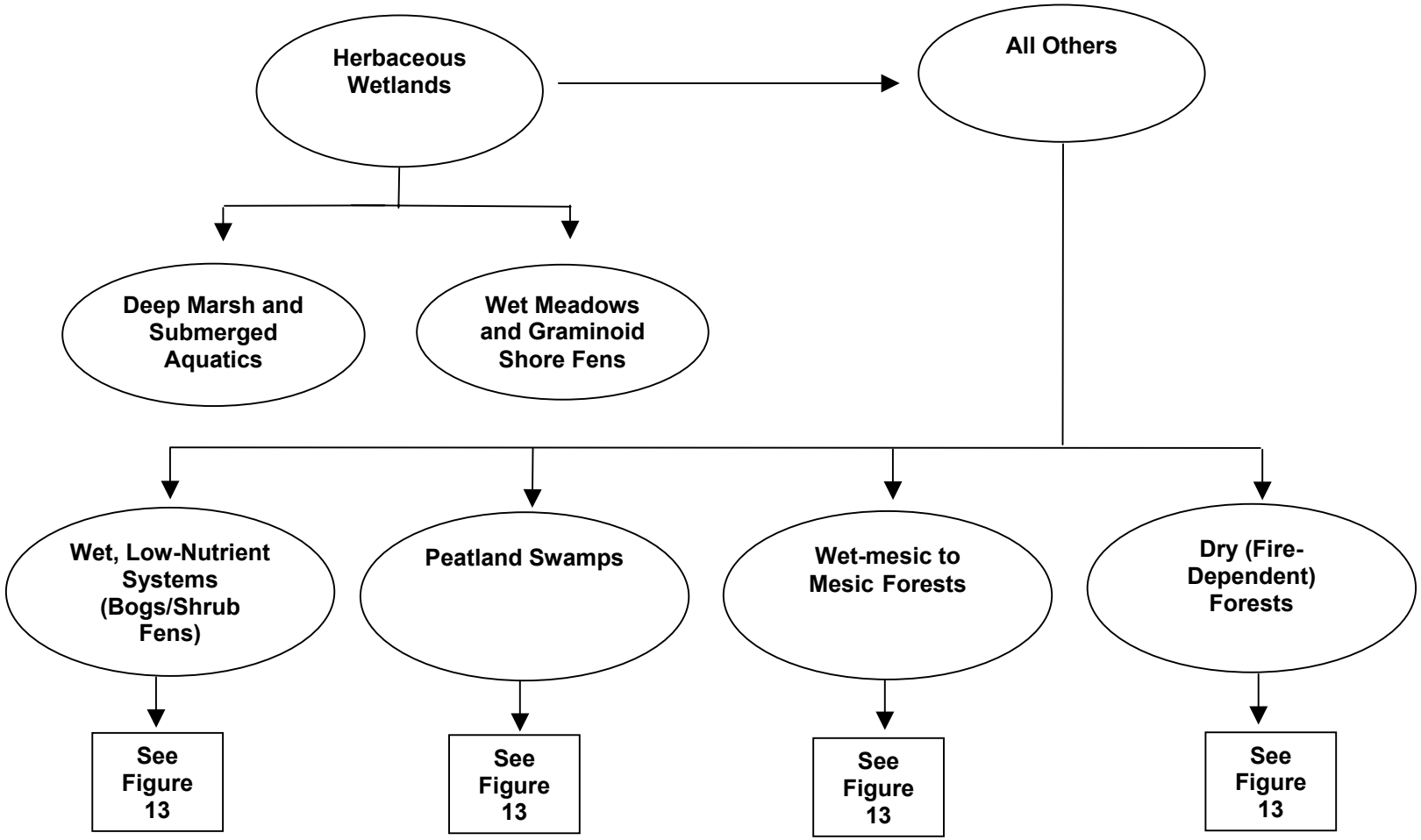

Figure 12. Flow chart of ordination subsets used to analyze the vegetation plot data
Each circled group indicates a subset of plots that were analyzed further to refine the types and assign them to specific associations.
See Figure 11 for rest of diagram.

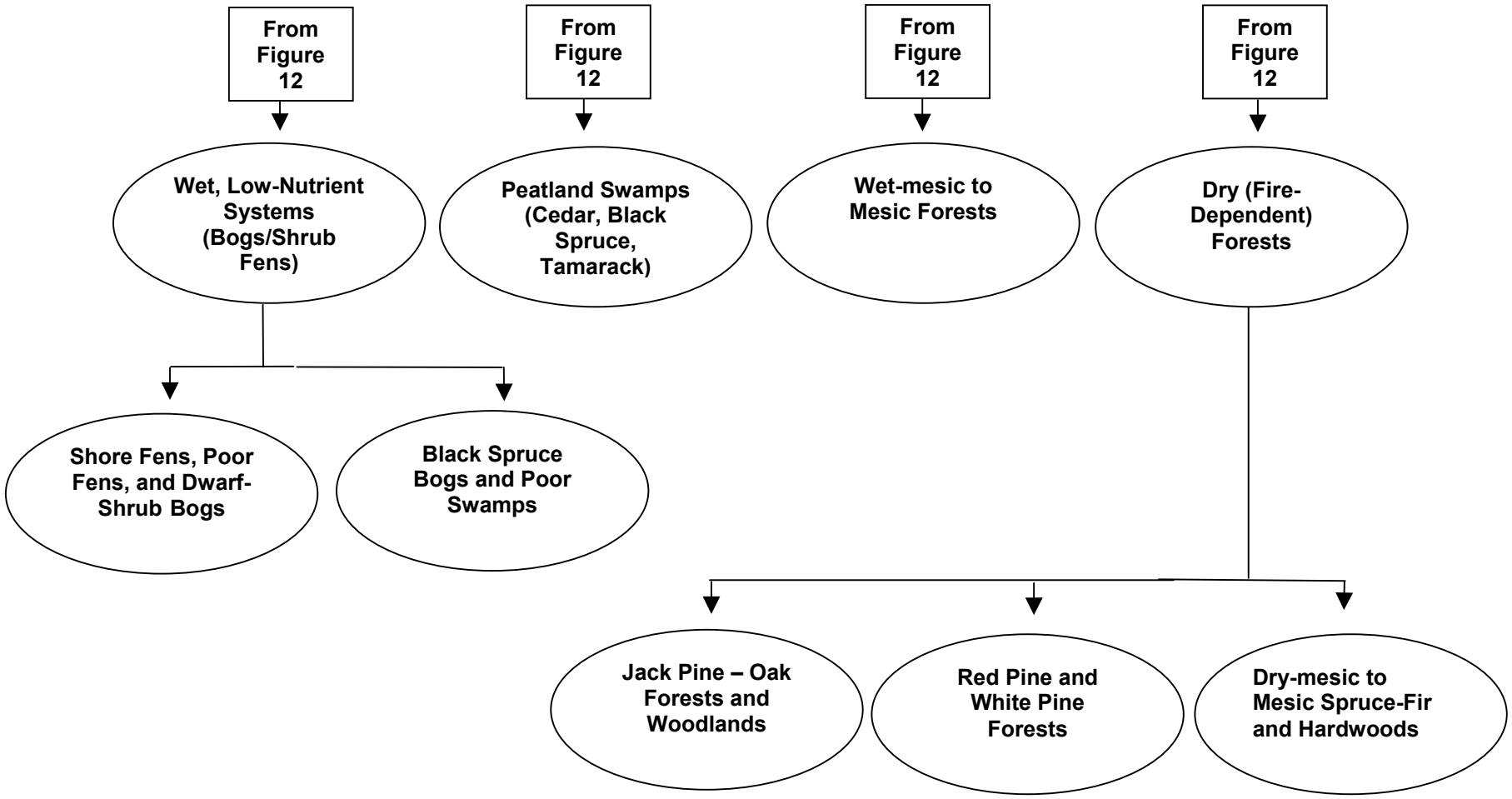

Figure 13. Flow chart of ordination subsets used to analyze the vegetation plot data
Each circled group indicates a subset of plots that were analyzed further to refine the types and assign them to specific associations.

The second subset, the conifer and alder swamps (which are primarily peatland swamps) include nutrient-rich white cedar swamps, white cedar-tamarack swamps, and alder swamps, and more moderately minerotrophic black spruce/alder and tamarack-(black spruce)/alder swamps. A scrub cedar-spruce-tamarack type is placed with the white cedar-tamarack swamp type, though it appears to be as related to the tamarack/alder type.

The third subset includes primarily the wet-mesic hardwood or mixed hardwood-conifer swamps and forests, though it also shows the split between that subset and the more fire-dependent upland spruce-fir and aspen types. Types include the black ash swamp, with some white cedar-black ash and wet-mesic white cedar upland forest, the aspen lowland forest, and the more mesic white cedar upland and white cedar-aspen-birch forests. The white cedar upland types grade from mesic upland to wet-mesic upland or lowland, where they overlap with white cedar-black ash swamps.

Finally, the fourth subset included all of the dry to dry-mesic pine and hardwood types. The analysis separated the drier jack pine and oak types from the red pine, white pine, and black spruce feathermoss types, and these in turn from the spruce-fir -aspen–birch types . These three sub-subsets were individually analyzed using ordination, TWINSPAN, and cluster analysis to further clarify their patterns. The jack pine and oak types were further refined into an open jack pine/lichen nonvascular type, a jack pine/fir type, and a heterogeneous set of jack pine or mixed pine-hardwood and pin oak-bur oak woodlands on bedrock (with a Dryweed Island subtype). The pin oak-bur oak woodland type overlapped considerably with a proposed jack pine-oak type. These were lumped together into a pin oak-bur oak-(jack pine) rocky woodland type that ranged from an overstory of pure oak to oak with jack pine. The Dryweed Island stands, which are on greenstone rather than biotite schist bedrock, are considered part of this type contingent on a wider review of the influence of the bedrock. In addition, the mixed pine-hardwood woodland also overlapped with the pin oak-bur oak- (jack pine) rocky woodland type, so the type was broadened to include mixtures of oak with red pine, white pine, and white spruce. The jack pine woodland, transitional between jack pine/fir forest and pin oak-bur oak-(jack pine) rocky woodland, was restricted in scope to be an evergreen jack pine rocky woodland type that ranged from pure jack pine to mixed pines.

The analysis of the second sub-subset (red and white pine types), using ordination and TWINSPAN separated the white pine types (both pure evergreen white pine and white pine-aspen) from the red pine types (both red pine and red pine-aspen types). Another cluster appeared to be a mixture of pine or oak types that had recently been burned. Although these appear to have some shared understory characteristics of their own, stands are placed with the types that contain similar overstory dominants.

Analysis of the third sub-subset (the dry-mesic to mesic spruce-fir and hardwood types) indicated a distinctive mesic bur oak forest type, a rocky aspen-birch woodland type, an aspen-birch type that has both dry and mesic phases, a mix of spruce fir and spruce-fir aspen types, and the black spruce/feathermoss type. The black spruce/feathermoss type overlaps with two moist jack pine/fir stands. The spruce-fir and spruce-fir-aspen types are only distinguishable based on an arbitrary canopy cover distinction between pure evergreen (> 75% conifers) and mixed evergreen-deciduous (25-75% conifer).

3.2 Ecological groups

Patterns among the vegetation communities (associations) can be portrayed through ecological groups; that is, groups of types that share similar ecological processes (Faber-Langendoen 2000, in press). A more formal definition can be stated as follows: “Ecological Systems are dynamic assemblages or complexes of plant and/or animal communities that (1) occur together on the landscape; (2) are tied together by similar ecological processes, underlying abiotic environmental factors or gradients; and (3) form a readily identifiable unit on the ground.” The use of ecological groups is a way of emphasizing

some of the ecological, rather than floristic or physiognomic, similarities among the types. Twelve ecological groups were used to organize the vegetation communities at Voyageurs National Park and its environs; 6 wetland groups and 6 upland groups (Table 3). These 12 groups were based on discussions with Minnesota state ecologists. The criteria used to define them include hydrology, peat, acidity, vegetation structure and major dominants, and moisture. These groups help to highlight the ecological diversity found at and near Voyageurs National Park.

Table 3. Vegetation communities (associations) recognized at Voyageurs National Park and environs for the Voyageurs National Park Vegetation Mapping Project.

Community Name (Association)	Common Name (Synonym)	Elcode*	Formation Code*
WETLANDS			
Bogs			
Treed Bogs			
Picea mariana / Ledum groenlandicum / Carex trisperma / Sphagnum spp. Forest	Black Spruce Bog	CEGL002485	I.A.8.N.g.
Shrub Bogs			
Picea mariana / Chamaedaphne calyculata / Sphagnum spp. Dwarf-Shrubland	Black Spruce / Leatherleaf Semi-treed Bog	CEGL005218	IV.A.1.N.g.
(Chamaedaphne calyculata) - Ledum groenlandicum - Kalmia polifolia Bog Dwarf-shrubland	Leatherleaf Bog	CEGL002498	IV.A.1.N.g.
Northern Shrub and Graminoid Fens			
Shrub Fens			
Alnus incana - Salix spp. - Betula pumila / Chamaedaphne calyculata Shrubland	Bog Birch - Willow Shore Fen	CEGL005227	III.B.2.N.g.
Chamaedaphne calyculata - Myrica gale / Carex lasiocarpa Dwarf-shrubland	Leatherleaf - Sweet Gale Shore Fen	CEGL005228	IV.A.1.N.g.
Larix laricina - Betula pumila / Chamaedaphne calyculata Shrubland	Tamarack Scrub Poor Fen	CEGL005226	III.B.2.N.g.
Betula pumila / Chamaedaphne calyculata / Carex lasiocarpa Shrubland	Bog Birch - Leatherleaf Poor Fen	CEGL002494	III.B.2.N.g.
Graminoid Fens			
Carex lasiocarpa - (Carex rostrata) - Equisetum fluviatile Herbaceous Vegetation	Wiregrass Sedge Shore Fen	CEGL005229	V.A.5.N.m.
Carex lasiocarpa - Carex oligosperma / Sphagnum spp. - Polytrichum spp. Herbaceous Vegetation	Northern Sedge Poor Fen	CEGL002265	V.A.5.N.m.
Wet Meadows			
Calamagrostis canadensis Eastern Herbaceous Vegetation [Provisional]	Canada Bluejoint Eastern Meadow	CEGL005174	V.A.5.N.k.
Carex (rostrata, utriculata) - Carex lacustris - (Carex vesicaria) Herbaceous Vegetation	Northern Sedge Wet Meadow	CEGL002257	V.A.5.N.k.
Marshes			
Emergent Marshes			
Phragmites australis Semipermanently Flooded Ruderal Herbaceous Vegetation	Eastern Reed Marsh	CEGL004141	V.A.5.N.l.
Scirpus acutus - (Scirpus fluviatilis) Freshwater Herbaceous Vegetation	Freshwater Bulrush Marsh	CEGL002225	V.A.5.N.l.
Typha spp. Midwest Herbaceous Vegetation	Midwest Cattail Deep Marsh	CEGL002233	V.A.5.N.l.
Equisetum fluviatile - (Eleocharis smallii) Herbaceous Vegetation	Water Horsetail - Spikerush Marsh	CEGL005258	V.B.2.N.e.
Zizania (aquatica, palustris) Herbaceous Vegetation [Provisional]	Wild Rice Marsh	CEGL002382	V.A.5.N.l.
Rooted and Floating Aquatic Marshes			
Potamogeton spp. - Ceratophyllum spp. Midwest Herbaceous Vegetation	Midwest Pondweed Submerged Aquatic Wetland	CEGL002282	V.C.2.N.a.
Nymphaea odorata - Nuphar lutea (ssp. pumila, variegata) Herbaceous Vegetation	Northern Water Lily Aquatic Wetland	CEGL002562	V.C.2.N.a.

Community Name (Association)	Common Name (Synonym)	Elcode*	Formation Code*
Northern Conifer and Hardwood Swamps			
Rich Hardwood Swamps			
Fraxinus nigra - Mixed Hardwoods-Conifers / Cornus sericea / Carex spp. Forest	Black Ash - Mixed Hardwood Swamp	CEGL002105	I.B.2.N.g.
Thuja occidentalis - Fraxinus nigra Forest	White Cedar - Black Ash Swamp	CEGL005165	I.C.3.N.d.
Rich Conifer Swamps			
Picea mariana / Alnus incana / Sphagnum spp. Forest	Black Spruce / Alder Rich Swamp	CEGL002452	I.A.8.N.g.
Larix laricina / Alnus incana Forest	Northern Tamarack Rich Swamp	CEGL002471	I.B.2.N.g.
Thuja occidentalis - (Picea mariana - Abies balsamea) / Alnus incana Forest	White Cedar - (Mixed Conifer) / Alder Swamp	CEGL002456	I.A.8.N.g.
Poor Conifer Swamps			
Picea mariana / Ledum groenlandicum / Sphagnum spp. Forest	Black Spruce / Labrador Tea Poor Swamp	CEGL002454	I.A.8.N.g.
Northern Shrub Swamps			
Cornus spp. - Salix discolor - (Rosa palustris) Shrubland	Dogwood - Pussy Willow Swamp	CEGL002186	III.B.2.N.e.
Alnus incana Swamp Shrubland [Provisional]	Speckled Alder Swamp	CEGL002381	III.B.2.N.e.
UPLANDS			
Rock Barrens			
Treed Rock Barrens			
Pinus banksiana - (Picea mariana, Pinus strobus) / Vaccinium spp. / Rocky Woodland	Boreal Pine Rocky Woodland	CEGL002483	II.A.4.N.a.
Pinus banksiana - Mixed Conifer / Cladonia spp. Nonvascular Vegetation	Jack Pine / Lichen Rocky Barrens	CEGL002491	VI.B.1.N.c.
Populus tremuloides - (Populus grandidentata) Rocky Woodland	Mixed Aspen Rocky Woodland	CEGL002487	II.B.2.N.a.
Quercus ellipsoidalis - Quercus macrocarpa - (Pinus banksiana) Rocky Woodland	Northern Pin Oak - Bur Oak - (Jack Pine) Rocky Woodland	CEGL005246	II.B.2.N.a.
Shrub and Herb Rock Barrens			
Corylus cornuta - Amelanchier spp. - Prunus virginiana Rocky Shrubland	Boreal Hazelnut - Serviceberry Rocky Shrubland	CEGL005197	III.B.2.N.a.
Danthonia spicata - Poa compressa Granite Herbaceous Vegetation	Poverty Grass Granite Barrens	CEGL005157	V.A.5.N.c.
Northern White Cedar-(Hardwood) Forests			
Thuja occidentalis / Abies balsamea - Acer spicatum Forest	White Cedar - Boreal Conifer Mesic Forest	CEGL002449	I.A.8.N.c.
Thuja occidentalis - Betula alleghaniensis Forest	White Cedar - Yellow Birch Forest	CEGL002450	I.C.3.N.a.
Northern Pine-(Hardwood) Forests			
Pinus banksiana - Populus tremuloides / Diervilla lonicera Forest	Jack Pine - Aspen / Bush Honeysuckle Forest	CEGL002518	I.C.3.N.a
Pinus banksiana / Abies balsamea Forest	Jack Pine / Balsam Fir Forest	CEGL002437	I.A.8.N.b.
Pinus resinosa - Populus tremuloides / Diervilla lonicera - Vaccinium spp. Forest	Red Pine - Aspen - Birch Forest	CEGL002520	I.C.3.N.a.
Pinus resinosa / Vaccinium spp. Forest	Red Pine / Blueberry Dry Forest	CEGL002443	I.A.8.N.b.
Pinus strobus - Populus tremuloides / Corylus cornuta Forest	White Pine - Aspen - Birch Forest	CEGL002479	I.C.3.N.a.
Pinus strobus / Acer spicatum - Corylus cornuta Forest	White Pine / Mountain Maple Mesic Forest	CEGL002445	I.A.8.N.b.
Northern Spruce-Fir-(Hardwood) Forests			
Abies balsamea - Betula papyrifera / Diervilla lonicera Forest	Balsam Fir - Paper Birch Forest	CEGL002474	I.A.8.N.c.
Picea mariana - Populus tremuloides / Mixed Herbs Forest	Black Spruce - Aspen Forest	CEGL002516	I.C.3.N.a.

Community Name (Association)	Common Name (Synonym)	Elcode*	Formation Code*
Picea mariana / Pleurozium schreberi Forest	Black Spruce / Feathermoss Forest	CEGL002447	I.A.8.N.c.
Picea glauca - Abies balsamea - Populus tremuloides / Mixed Herbs Forest	Spruce - Fir - Aspen Forest	CEGL002475	I.C.3.N.a.
Picea glauca - Abies balsamea / Acer spicatum / Rubus pubescens Forest	Spruce-Fir / Mountain Maple Forest	CEGL002446	I.A.8.N.c.
Boreal Hardwood Forests			
Populus tremuloides - Betula papyrifera / (Abies balsamea, Picea glauca) Forest	Aspen - Birch / Boreal Conifer Forest	CEGL002466	I.B.2.N.b.
Populus tremuloides - Betula papyrifera - (Acer rubrum, Populus grandidentata) Forest	Aspen - Birch - Red Maple Forest	CEGL002467	I.B.2.N.b.
Betula papyrifera / Diervilla lonicera - (Abies balsamea) Forest	Paper Birch / Fir Forest	CEGL002463	I.B.2.N.b.
Populus tremuloides - Populus balsamifera - Mixed Hardwoods Lowland Forest	Trembling Aspen - Balsam Poplar Lowland Forest	CEGL005036	I.B.2.N.d.
Northern Hardwood Forests			
Quercus macrocarpa / Amelanchier alnifolia / Aralia nudicaulis - Carex assiniboinensis Forest	Northern Bur Oak Mesic Forest	CEGL002072	I.B.2.N.a.

* Elcode is the USNVC database code (CEGL) for each vegetation association. The Formation code for each association is also listed. This code refers to the Formation level name in the USNVC.

3.3 Global rarity

TNC and the Natural Heritage Network assess plant communities as to rarity and degree of imperilment. Ranks indicating the range wide (global) conservation status have been developed for nearly all of the identified communities occurring in the United States. The communities are ranked on a global (G) scale of 1 to 5, with 1 indicating critical imperilment due to rarity, endemism, and/or threats, and 5 indicating little or no risk of extirpation or elimination. For example, a rank of G1 indicates critical imperilment on a range wide basis, i.e., a great risk of "extinction" of the type worldwide. A few plant communities (associations) at and near Voyageurs National Park are globally imperiled. Two associations are listed as Vulnerable or Apparently Secure (G3G4): the Northern Sedge Poor Fen and the White Pine / Mountain Maple Mesic Forest (Figure 14). The Red Pine / Blueberry Dry Forest Association is listed as a G3. The potentially most imperiled community, White Cedar - Yellow Birch Forest Association, is a G2Q, meaning that it is Imperiled. However, until the taxonomic uncertainty around this association is resolved, the rank is still in doubt. One association that has not yet been ranked, but may prove to be rare is the Northern Bur Oak Mesic Forest. It is worth noting that the more imperiled plant communities found within and around the park are primarily upland types.

Figure 14. Northern Sedge Poor Fen: Global Rarity of G3G4

3.4 Map Units

Sixty-seven map units were used to map Voyageurs National Park and environs (Table 4). Fifty-three of these map units represent vegetation types that belong to the USNVC (Appendix B). The map units relate to the USNVC hierarchy at different levels. Forty-three of the 53 map units represent associations (or phases of associations), the finest level of the USNVC hierarchy. Three map units represent the USNVC at the alliance level. Three map units represent the USNVC at the formation level. These map units represent evergreen plantations and perennial grass crops. Last, 4 map units represent more than one formation. These 4 map units were created to handle vegetation patterns that were too complicated or intricate to map at finer levels of the USNVC.

Eight map units represent categories of developed land use such as urban, agricultural lands, commercial services, and transportation areas, or unvegetated water such as lakes and streams (Anderson et al. 1976). Six additional park-specific map units were developed to capture small upland islands (0.1 - 0.5 h) and small natural ponds (<16 h in size and <10% vegetated).

Table 4. Map units and related levels within the US National Vegetation Classification (USNVC) or Anderson et al. (1976) for Voyageurs National Park.
Map units are organized by Ecological Groups.

MAP UNIT CODE	MAP UNIT NAME	LEVEL
Natural/Semi-natural Vegetation Map Units		
Bogs		
Treed Bogs		
BSB	Black Spruce Bog	Association
Shrub Bogs		
LBC	Black Spruce/Leatherleaf Semi-treed Bog	Association
LB	Leatherleaf Bog	Association
BBX	Beaver Basin Break-up Mosaic	Map Unit
Northern Shrub and Graminoid Fens		
Shrub Fens		
BBSF	Bog Birch-Willow Shore Fen	Association
LSF	Leatherleaf-Sweet Gale Shore Fen	Association
TF	Tamarack Scrub Poor Fen	Association
Graminoid Fens		
SPF	Northern Sedge Poor Fen	Association
Wet Meadows		
BJ	Canada Bluejoint Eastern Meadow	Association
SMX	Wet Meadow/Fen Mosaic/Complex	Map Unit
Marshes		
Emergent Marshes		
PM	Eastern Reed Marsh	Association
BM	Freshwater Bulrush Marsh	Association
CM	Midwest Cattail Deep Marsh	Association
WRM	Wild Rice Marsh	Association
DMX	Deep Marsh Mosaic/Complex	Map Unit
Rooted and Floating Aquatic Marshes		
PW	Midwest Pondweed Submerged Aquatic Wetland	Association
WL	Northern Water Lily Aquatic Wetland	Association

MAP UNIT CODE	MAP UNIT NAME	LEVEL
Northern Conifer and Hardwood Swamps		
Rich Hardwood Swamps		
BA	Black Ash-Mixed Hardwood Swamp	Association
WCBA	White Cedar-Black Ash Swamp	Association
Rich Conifer Swamps		
BSAS	Black Spruce/Alder Rich Swamp	Association
TA	Northern Tamarack Rich Swamp	Association
WCS	White Cedar-(Mixed Conifer)/Alder Swamp (rich soil phase)	Association
WCT	White Cedar-(Mixed Conifer)/Alder Swamp (peatland phase)	Association
Poor Conifer Swamps		
BSL	Black Spruce/Labrador Tea Poor Swamp (evergreen phase)	Association
BST	Black Spruce/Labrador Tea Poor Swamp (mixed phase)	Association
Northern Shrub Swamps		
DS	Dogwood-Pussy Willow Swamp	Association
AS	Speckled Alder Swamp	Association
Rock Barrens		
Treed Rock Barrens		
JPW	Boreal Pine Rocky Woodland (jack pine phase)	Association
JPM	Boreal Pine Rocky Woodland (mixed pine phase)	Association
JPL	Jack Pine/Lichen Rocky Barrens	Association
ABW	Mixed Aspen Rocky Woodland	Association
OW	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (deciduous phase)	Association
JPOM	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (jack pine-oak phase)	Association
MPHW	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (mixed pine-oak phase)	Association
Shrub and Herb Rock Barrens		
UBS	Boreal Hazelnut-Serviceberry Rocky Shrubland	Association
MGF	Poverty Grass Granite Barrens	Association
Northern White Cedar-(Hardwood) Forests		
WCU	White Cedar-Boreal Conifer Mesic Forest	Association
WCA	White Cedar-Yellow Birch Forest	Association
Northern Pine-(Hardwood) Forests		
JPAX	Jack Pine-Aspen Forest Mosaic	Map Unit
JPF	Jack Pine/Balsam Fir Forest	Association
WRPA	White Pine-Red Pine-Quaking Aspen-Birch Forest	Alliance
RP	Red Pine/Blueberry Dry Forest	Association
WP	White Pine/Mountain Maple Mesic Forest	Association
Northern Spruce-Fir-(Hardwood) Forests		
SFA	Spruce-Fir-Aspen Forest	Alliance
BSF	Black Spruce/Feathermoss Forest	Association
SF	Spruce-Fir/Mountain Maple Forest	Association
Boreal Hardwood Forests		
AB	Quaking Aspen-Paper Birch Forest	Alliance
PB	Paper Birch/Fir Forest	Association
AL	Trembling Aspen-Balsam Poplar Lowland Forest	Association
Northern Hardwood Forests		
BO	Northern Bur Oak Mesic Forest	Association

MAP UNIT CODE	MAP UNIT NAME	LEVEL
Planted/Cultivated, Land Use/Land Cover, and Park Specific Map Units		
Planted/Cultivated Vegetation (USNVC)		
EP	Evergreen Plantation	Formation
PGCH	Perennial Grass Crops (hay, pastureland)	Formation
PGCS	Perennial Grass Crops with Sparse Shrubs (hay, pastureland)	Formation
Land Use/Land Cover (USGS - Anderson Level II)		
Developed Lands		
ACP	Cropland and Pasture	LUC II
ARB	Other Agricultural Land	LUC II
BLQ	Strip Mines, Quarries, and Gravel Pits	LUC II
UC	Commercial and Services	LUC II
UR	Residential	LUC II
UT	Transportation, Communications, and Utilities	LUC II
Lakes and Streams		
WLK	Lakes (>16 ha)	LUC II
WS	Streams and Canals	LUC II
Small Islands and Natural Ponds (Park Specific)		
Small Islands (0.1 - .05 h)		
SIG	Small Island with Grass	Park
SIR	Small Island with Rock	Park
SIS	Small Island with Shrubs	Park
SIT	Small Island with Trees	Park
Small Natural Ponds (<10% vegetated)		
WBP	Water-Beaver Pond	Park
WNP	Water-Natural Pond (<16 h)	Park

Association Level Map Units

Forty-three map units represent associations, the finest level of the USNVC hierarchy. Twenty-one of these map units share a one-to-one relationship with a vegetation association. For example, Jack Pine/Lichen Rocky Barrens Map Unit (JPL) represents only one vegetation association, Jack Pine / Lichen Rocky Barrens Association. Nine of the remaining 22 map units represent association phases (see below). Phases can be distinguished on the photographs because canopy dominance is different (e.g. jack pine phase versus a mixed pine-oak phase) but the phases are floristically similar. Map unit phases were initially thought to be associations until late in the mapping process, after analysis of the vegetation plot data was completed. The remaining 13 map units represent either a single association, or they are represented within an aggregate map unit because of mapping complexity and photo limitations. Four aggregate map units were made to handle these situations.

Map Units Representing Association Phases

The Black Spruce / Labrador Tea Poor Swamp Association has 2 map unit phases: an evergreen phase dominated by black spruce (Black Spruce/Labrador Tea Poor Swamp (evergreen phase); BSL, Figure 15), and a mixed phase with black spruce and tamarack sharing dominance (Black Spruce/Labrador Tea Poor Swamp (mixed phase); BST). BSL was applied to polygons where black spruce dominates, and BST was applied to the mixed phase. The phases are recognizable from each other on the aerial photographs, and were initially thought to be 2 different associations.

Figure 15. A Black Spruce / Labrador Tea Poor Swamp Association
This stand was mapped as the evergreen phase, BSL.

The Boreal Pine Rocky Woodland Association has 2 map unit phases: a jack pine phase, (Boreal Pine Rocky Woodland (jack pine phase); JPW), and a mixed pine phase, (Boreal Pine Rocky Woodland (mixed pine phase); JPM). JPW was applied to polygons where jack pine dominated the canopy, and JPM was applied to polygons where the evergreen component was of mixed pine species. The phases are recognizable from each other on the aerial photographs, and were initially thought to be 2 different associations.

The Northern Pin Oak - Bur Oak - (Jack Pine) Rocky Woodland Association has 3 map unit phases depending on relative canopy dominance: a deciduous phase, (Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (deciduous phase); OW), a jack pine and pin oak phase, (Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (jack pine-oak phase); JPOM), and a mixed pine and oak phase (Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (mixed pine-oak phase); MPHW). The phases are recognizable from each other on the aerial photographs, and were initially thought to be 3 different associations.

The White Cedar- (Mixed Conifer)/Alder Swamp Association has 2 map unit phases: a phase with tamarack present in the canopy or in the emergent layer (White Cedar-(Mixed Conifer)/Alder Swamp Map Unit (peatland phase); WCT) and a phase lacking tamarack (White Cedar-(Mixed Conifer)/Alder Swamp (rich soil phase); WCS). The phases are recognizable from each other on the aerial photographs, and were initially thought to be 2 different associations.

Map Units Representing Alliances

Three map units reflect alliance levels of the USNVC. These map units include more than one association within the same alliance. Alliance level map units were necessary for mapping because the individual associations within the alliance do not have unique photo signatures.

The Quaking Aspen-Paper Birch Forest Map Unit (AB) includes two associations in the Quaking Aspen - Birch Forest Alliance: the Aspen - Birch / Boreal Conifer Forest and the Aspen - Birch - Red Maple Forest. The differences between the 2 associations were not visible on the aerial photographs

because closed canopy situations disguised the sub-canopy floristics. In addition, the Aspen - Birch - Red Maple Forest Association is the less common of the 2, and where red maple occurs in the sub-canopy with balsam fir, the stand is considered an Aspen - Birch / Boreal Conifer Forest Association. Although the map unit represents two associations, any one polygon mapped as AB could represent either or both associations.

The White Pine-Red Pine-Quaking Aspen-Birch Forest Map Unit (WRPA) includes 2 associations from the White Pine - (Red Pine) - Quaking Aspen Forest Alliance: the White Pine - Aspen - Birch Forest and the Red Pine Aspen Birch Forest. The two associations were mapped as one map unit because they were not easily distinguished from one another on the aerial photographs. WRPA is also an aggregate map unit, containing other associations that occur together in a mosaic pattern (e.g. WP and AB, see below). Although the map unit represents two associations or an aggregate of other map units, any one polygon mapped as WRPA could represent either or both associations, or an aggregate of map units.

The Spruce-Fir-Aspen Forest Map Unit (SFA) includes two associations from two different alliances. SFA is not Formation level mapping because other alliances within the same formation were mapped separately (e.g. JPAX, WRPA, WCA). The Spruce - Fir - Aspen Forest Association is from the White Spruce - Balsam Fir - Aspen Alliance and the Black Spruce - Aspen Forest Association is from the Black Spruce - Quaking Aspen Forest Alliance. These two associations could not be distinguished from one another on the aerial photographs because their signatures are similar. Although the map unit represents two associations, any one polygon mapped as SFA could represent either or both associations.

The Tamarack Scrub Poor Fen Map Unit (TF) includes 2 associations: the Tamarack Scrub Poor Fen and the Bog Birch - Leatherleaf Poor Fen. However, the Bog Birch - Leatherleaf Poor Fen is considered an inclusion to TF because it generally occurs in small stands and is considered a minor type. The TF map unit is considered an association level map unit, but is mentioned here for clarification. In addition, the Bog Birch - Leatherleaf Poor Fen Association could not be clearly distinguished on the aerial photographs from the Tamarack Scrub Poor Fen Association. Notice in Table 5 that Bog Birch - Leatherleaf Poor Fen is listed as an inclusion to the TF Map Unit.

The Spruce-Fir/Mountain Maple Forest Map Unit (SF) includes 2 associations: the Spruce - Fir / Mountain Maple Forest and the Balsam Fir - Paper Birch Forest. The latter is a very minor type and could not be clearly distinguished on the aerial photographs from the Spruce - Fir / Mountain Maple Forest Association. Thus, it was mapped as part of the Spruce - Fir / Mountain Maple Forest Association. Like TF, the SF map unit is considered is an association level map unit.

Map Units Representing Formations

Three map units represent the classification hierarchy at the formation level and are the Evergreen Plantation Map Unit (EP), the Perennial Grass Crops Map Unit (PGCH) and the Perennial Grass Crops with Sparse Shrubs (PGCS). The 3 formations represented by these map units fall under the Planted/Cultivated Subgroup of the USNVC.

Map Units that are Aggregates (more than one Formation)

Five map units are aggregates of vegetation associations. Each unit combines ecologically linked associations that consistently occur together in the landscape. The aggregates were created because sometimes the individual vegetation associations occurring together could not be distinguished from one another on the aerial photographs because they look alike, or the pattern of several associations occurring together is too intricate to map. There are photo interpretation terms for both these situations.
COMPLEX: The individual communities are not recognizable on the aerial photographs but repeatedly occur together in the landscape**.** Complexes typically are composed of communities with similar

physiognomies, thus, are more difficult to tell apart on the photo. **MOSAIC:** The individual communities are recognizable on the aerial photographs but occur in an intermixed pattern too intricate to map as separate polygons. Mosaics are typically composed of communities with different physiognomies - that is why they are visibly different appearing on the photo. **COMPLEX/MOSAIC**: In many situations, these map unit concepts overlap with one another; we might be able to see individual communities that are too small to map, but other communities exist within the same polygon that have similar signatures.

The Wet Meadow/Fen Mosaic/Complex Map Unit (SMX) includes 5 associations: Canada Bluejoint Eastern Meadow, Northern Sedge Wet Meadow, Wiregrass Sedge Shore Fen, Eastern Reed Marsh, and Midwest Cattail Deep Marsh. In any given polygon designated as SMX, one or more of these communities might occur. Midwest Cattail Deep Marsh and Eastern Reed Marsh were included in this map unit only when found in relatively shallow water. They were mapped with the Deep Marsh Mosaic/Complex Map Unit (DMX) when occurring in deeper water. Three of the 5 associations may be mapped individually if they reach at least the minimum mapping unit of 0.5 h in size and are recognizable on the aerial photograph. The Wiregrass Sedge Shore Fen and the Northern Sedge Wet Meadow were never mapped as individual map units. The Northern Sedge Wet Meadow can also be part of Beaver Basin Break-up Mosaic Map Unit.

Figure 16. One example of vegetation mapped using the SMX Map Unit

The Deep Marsh Mosaic/Complex Map Unit (DMX) includes 7 associations: Eastern Reed Marsh, Freshwater Bulrush Marsh, Midwest Cattail Deep Marsh, Wild Rice Marsh, Water Horsetail-Spikerush Marsh, Northern Water Lily Aquatic Wetland, and Midwest Pondweed Submerged Aquatic Wetland. Midwest Cattail Deep Marsh and Eastern Reed Marsh associations also occur as part of SMX when in shallower water. Horsetail-Spikerush Marsh does not exist as an individual map unit. The Midwest Pondweed Submerged Aquatic Wetland, and the Northern Water Lily Aquatic Wetland associations were each mapped individually if occurring singularly (at least 0.5 h), and could be recognized on the aerial photograph. They were also mapped within the BBX Map Unit under.

The Beaver Basin Break-up Mosaic Map Unit (BBX), includes 6 associations: Leatherleaf Bog, Black Spruce / Leatherleaf Semi-treed Bog, Leatherleaf - Sweet Gale Shore Fen, Northern Sedge Wet Meadow, Northern Water Lily Aquatic Wetland, and Midwest Pondweed Submerged Aquatic Wetland. The associations often occur in a spatial pattern too intricate to map individually, occurring where beaver activity has caused ericaceous mats to break up. The mats become partly flooded, creating pockets of wet sedges or in deeper zones, water lilies and pondweeds. A polygon mapped as BBX includes at least one

dwarf shrub and one herbaceous association. Any association included in BBX was mapped individually if occurring singularly, visible on the aerial photograph, and at least 0.5 h.

The White Pine-Red Pine-Quaking Aspen-Birch Forest Map Unit (WRPA) includes 6 associations when mapped as a mosaic: White Pine - Aspen - Birch Forest, Red Pine Aspen Birch Forest, Red Pine / Blueberry Dry Forest, White Pine / Mountain Maple Mesic Forest, Aspen - Birch / Boreal Conifer Forest, and the Aspen Birch / Red Maple Forest. When WRPA was used to map a combination of pine and aspen forest types, it was mapped as such because the forests occurred in a mosaic pattern with each other. Another way to describe WRPA when mapped as a mosaic is by the combinations of Map Units RP and/or WP with Map Unit AB. WRPA also represents an Alliance level map unit with 2 pine-aspen associations, as discussed previously.

The Jack Pine-Aspen Forest Mosaic Map Unit (JPAX) represents 4 associations: Jack Pine / Balsam Fir Forest, Aspen-Birch / Boreal Conifer Forest, Aspen-Birch-Red Maple Forest, and Jack Pine-Aspen / Bush Honeysuckle Forest (Figure 15). When JPAX was used to map a combination of jack pine and aspen forest types, it was mapped as such because forests occurred in a mosaic pattern with each other. Another way to describe JPAX when mapped as a mosaic is by the combinations of Map Unit JPF with Map Unit AB. Occasionally, the map unit represents the true mixed forest association of Jack Pine-Aspen / Bush Honeysuckle Forest.

Figure 17. A Jack Pine / Balsam Fir Forest
One of the associations included in the Jack Pine-Aspen Mosaic Map Unit (JPAX)

Table 5 shows the relationship of each vegetation association to the map unit or map units. The first 2 columns present the USNVC associations and their common names. The third column gives the USNVC Community Element Global database codes for each association, and the fourth column presents the USNVC codes to the formation level from Grossman et al. (1998). The last column shows the map unit codes that link to each association. As explained in previous paragraphs, some associations are mapped by more than one map unit. The map unit codes under the Map Unit Link column that are followed by the word “shares” or another map unit code in parentheses means the association is also part of another

map unit. For example, the Leatherleaf Bog Association is mapped as LB when it occurs alone, but it is also mapped as BBX when the association occurs as a mosaic with other associations within certain beaver floodings. Some map units, such as SFA, include more than one association. These map units have the word "shares" in parentheses. Still others, such as AB, include 2 associations (shares), yet these associations are also part of mosaic/complex map units (JPAX & WRPA). Map units that are phases of the same association, such as BSL and BST, are listed together in the same cell. See text below for a complete discussion of these relationships. Appendix B also shows the relationships between associations and map units.

For specific details about each map unit, how they were used in mapping, and their relationship to vegetation communities, see Appendix F, *Photo Interpretation Mapping Conventions and Visual Key*.

Table 5. Crosswalk of vegetation associations to map units.

COMMUNITY NAME (ASSOCIATION)	COMMON NAME (SYNONYM)	ELCODE	FORMATION	MAP UNIT LINK
Bogs				
Treed Bogs				
Picea mariana / Ledum groenlandicum / Carex trisperma / Sphagnum spp. Forest	Black Spruce Bog	CEGL002485	I.A.8.N.g.	BSB
Shrub Bogs				
Picea mariana / Chamaedaphne calyculata / Sphagnum spp. Dwarf-shrubland	Black Spruce / Leatherleaf Semi-treed Bog	CEGL005218	IV.A.1.N.g.	LBC (BBX when mosaic/complex)
(Chamaedaphne calyculata) - Ledum groenlandicum - Kalmia polifolia Bog Dwarf-shrubland	Leatherleaf Bog	CEGL002498	IV.A.1.N.g.	LB (BBX when mosaic/complex)
Northern Shrub and Graminoid Fens				
Shrub Fens				
Alnus incana - Salix spp. - Betula pumila / Chamaedaphne calyculata Shrubland	Bog Birch - Willow Shore Fen	CEGL005227	III.B.2.N.g.	BBSF
Chamaedaphne calyculata - Myrica gale / Carex lasiocarpa Dwarf-Shrubland	Leatherleaf - Sweet Gale Shore Fen	CEGL005228	IV.A.1.N.g.	LSF (BBX when mosaic/complex)
Larix laricina - Betula pumila / Chamaedaphne calyculata Shrubland	Tamarack Scrub Poor Fen	CEGL005226	III.B.2.N.g.	TF
Betula pumila / Chamaedaphne calyculata / Carex lasiocarpa Shrubland	Bog Birch - Leatherleaf Poor Fen	CEGL002494	III.B.2.N.g.	inclusion within TF
Graminoid Fens				
Carex lasiocarpa - (Carex rostrata) - Equisetum fluviatile Herbaceous Vegetation	Wiregrass Sedge Shore Fen	CEGL005229	V.A.5.N.m.	SMX (shares)
Carex lasiocarpa - Carex oligosperma / Sphagnum spp. - Polytrichum spp. Herbaceous Vegetation	Northern Sedge Poor Fen	CEGL002265	V.A.5.N.m.	SPF
Wet Meadows				
Calamagrostis canadensis Eastern Herbaceous Vegetation [Provisional]	Canada Bluejoint Eastern Meadow	CEGL005174	V.A.5.N.k.	BJ (SMX when mosaic/complex)
Carex (rostrata, utriculata) - Carex lacustris - (Carex vesicaria) Herbaceous Vegetation	Northern Sedge Wet Meadow	CEGL002257	V.A.5.N.k.	SMX (shares)
Marshes				
Emergent Marshes				
Phragmites australis Semipermanently Flooded Ruderal Herbaceous Vegetation	Eastern Reed Marsh	CEGL004141	V.A.5.N.l.	PM (DMX & SMX when mosaic/complex)
Scirpus acutus - (Scirpus fluviatilis) Freshwater Herbaceous Vegetation	Freshwater Bulrush Marsh	CEGL002225	V.A.5.N.l.	BM (DMX when mosaic/complex)
Typha spp. Midwest Herbaceous Vegetation	Midwest Cattail Deep Marsh	CEGL002233	V.A.5.N.l.	CM (DMX & SMX when mosaic/complex)
Equisetum fluviatile - (Eleocharis smallii) Herbaceous Vegetation	Water Horsetail - Spikerush Marsh	CEGL005258	V.B.2.N.e.	DMX (shares)

COMMUNITY NAME (ASSOCIATION)	COMMON NAME (SYNONYM)	ELCODE	FORMATION	MAP UNIT LINK
Zizania (aquatica, palustris) Herbaceous Vegetation [Provisional]	Wild Rice Marsh	CEGL002382	V.A.5.N.I.	WRM (DMX when mosaic/complex)
Rooted and Floating Aquatic Marshes				
Potamogeton spp. - Ceratophyllum spp. Midwest Herbaceous Vegetation	Midwest Pondweed Submerged Aquatic Wetland	CEGL002282	V.C.2.N.a.	PW (DMX & BBX when mosaic/complex)
Nymphaea odorata - Nuphar lutea (ssp. pumila, variegata) Herbaceous Vegetation	Northern Water Lily Aquatic Wetland	CEGL002562	V.C.2.N.a.	WL (DMX & BBX when mosaic/complex)
Northern Conifer and Hardwood Swamps				
Rich Hardwood Swamps				
Fraxinus nigra - Mixed Hardwoods-Conifers / Cornus sericea / Carex spp. Forest	Black Ash - Mixed Hardwood Swamp	CEGL002105	I.B.2.N.g.	BA
Thuja occidentalis - Fraxinus nigra Forest	White Cedar - Black Ash Swamp	CEGL005165	I.C.3.N.d.	WCBA
Rich Conifer Swamps				
Picea mariana / Alnus incana / Sphagnum spp. Forest	Black Spruce / Alder Rich Swamp	CEGL002452	I.A.8.N.g.	BSAS
Larix laricina / Alnus incana Forest	Northern Tamarack Rich Swamp	CEGL002471	I.B.2.N.g.	TA
Thuja occidentalis - (Picea mariana - Abies balsamea) / Alnus incana Forest	White Cedar - (Mixed Conifer) / Alder Swamp	CEGL002456	I.A.8.N.g.	WCS & WCT
Poor Conifer Swamps				
Picea mariana / Ledum groenlandicum / Sphagnum spp. Forest	Black Spruce / Labrador Tea Poor Swamp	CEGL002454	I.A.8.N.g.	BSL (evergreen) & BST (mixed)
Northern Shrub Swamps				
Cornus spp. - Salix discolor - (Rosa palustris) Shrubland	Dogwood - Pussy Willow Swamp	CEGL002186	III.B.2.N.e.	DS
Alnus incana Swamp Shrubland [Provisional]	Speckled Alder Swamp	CEGL002381	III.B.2.N.e.	AS
Rock Barrens				
Treed Rock Barrens				
Pinus banksiana - (Picea mariana, Pinus strobus) / Vaccinium spp. Rocky Woodland	Boreal Pine Rocky Woodland	CEGL002483	II.A.4.N.a.	JPW (jack pine) & JPM (mixed pine)
Pinus banksiana - Mixed Conifer / Cladonia spp. Nonvascular Vegetation	Jack Pine / Lichen Rocky Barrens	CEGL002491	VI.B.1.N.c.	JPL
Populus tremuloides - (Populus grandidentata) Rocky Woodland	Mixed Aspen Rocky Woodland	CEGL002487	II.B.2.N.a.	ABW
Quercus ellipsoidalis - Quercus macrocarpa - (Pinus banksiana) Rocky Woodland	Northern Pin Oak - Bur Oak - (Jack Pine) Rocky Woodland	CEGL005246	II.B.2.N.a.	OW (deciduous), JPOM (jack pine-oak), & MPHW (mixed pine-oak)
Shrub and Herb Rock Barrens				
Corylus cornuta - Amelanchier spp. - Prunus virginiana Rocky Shrubland	Boreal Hazelnut - Serviceberry Rocky Shrubland	CEGL005197	III.B.2.N.a.	UBS
Danthonia spicata - Poa compressa Granite Herbaceous Vegetation	Poverty Grass Granite Barrens	CEGL005157	V.A.5.N.c.	MGF
Northern White Cedar-(Hardwood) Forests				
Thuja occidentalis / Abies balsamea - Acer spicatum Forest	White Cedar - Boreal Conifer Mesic Forest	CEGL002449	I.A.8.N.c.	WCU
Thuja occidentalis - Betula alleghaniensis Forest	White Cedar - Yellow Birch Forest	CEGL002450	I.C.3.N.a.	WCA
Northern Pine-(Hardwood) Forests				
Pinus banksiana - Populus tremuloides / Diervilla lonicera Forest	Jack Pine - Aspen / Bush Honeysuckle Forest	CEGL002518	I.C.3.N.a	JPAX (shares)
Pinus banksiana / Abies balsamea Forest	Jack Pine / Balsam Fir Forest	CEGL002437	I.A.8.N.b.	JPF (JPAX when mosaic with AB)

COMMUNITY NAME (ASSOCIATION)	COMMON NAME (SYNONYM)	ELCODE	FORMATION	MAP UNIT LINK
Pinus resinosa - Populus tremuloides / Diervilla lonicera - Vaccinium spp. Forest	Red Pine - Aspen - Birch Forest	CEGL002520	I.C.3.N.a.	WRPA (shares)
Pinus resinosa / Vaccinium spp. Forest	Red Pine / Blueberry Dry Forest	CEGL002443	I.A.8.N.b.	RP (WRPA when mosaic with AB)
Pinus strobus - Populus tremuloides / Corylus cornuta Forest	White Pine - Aspen - Birch Forest	CEGL002479	I.C.3.N.a.	WRPA (shares)
Pinus strobus / Acer spicatum - Corylus cornuta Forest	White Pine / Mountain Maple Mesic Forest	CEGL002445	I.A.8.N.b.	WP (WRPA when mosaic with AB)
Northern Spruce-Fir-(Hardwood) Forests				
Abies balsamea - Betula papyrifera / Diervilla lonicera Forest	Balsam Fir - Paper Birch Forest	CEGL002474	I.A.8.N.c.	minor within SF
Picea mariana - Populus tremuloides / Mixed Herbs Forest	Black Spruce - Aspen Forest	CEGL002516	I.C.3.N.a.	SFA (shares)
Picea mariana / Pleurozium schreberi Forest	Black Spruce / Feathermoss Forest	CEGL002447	I.A.8.N.c.	BSF
Picea glauca - Abies balsamea - Populus tremuloides / Mixed Herbs Forest	Spruce - Fir - Aspen Forest	CEGL002475	I.C.3.N.a.	SFA (shares)
Picea glauca - Abies balsamea / Acer spicatum / Rubus pubescens Forest	Spruce-Fir / Mountain Maple Forest	CEGL002446	I.A.8.N.c.	SF
Boreal Hardwood Forests				
Populus tremuloides - Betula papyrifera / (Abies balsamea, Picea glauca) Forest	Aspen - Birch / Boreal Conifer Forest	CEGL002466	I.B.2.N.b.	AB (shares, JPAX & WRPA when mosaic)
Populus tremuloides - Betula papyrifera - (Acer rubrum, Populus grandidentata) Forest	Aspen - Birch - Red Maple Forest	CEGL002467	I.B.2.N.b.	AB (shares, JPAX & WRPA when mosaic)
Betula papyrifera / Diervilla lonicera - (Abies balsamea) Forest	Paper Birch / Fir Forest	CEGL002463	I.B.2.N.b.	PB
Populus tremuloides - Populus balsamifera - Mixed Hardwoods Lowland Forest	Trembling Aspen - Balsam Poplar Lowland Forest	CEGL005036	I.B.2.N.d.	AL
Northern Hardwood Forests				
Quercus macrocarpa / Amelanchier alnifolia / Aralia nudicaulis - Carex assiniboinensis Forest	Northern Bur Oak Mesic Forest	CEGL002072	I.B.2.N.a.	BO

3.5 Vegetation Map

A total area of 156,886 h was mapped of Voyageurs National Park and environs, including a portion of Canada (Table 6). Of this total, vegetated map units represent >100,000 h. The remaining map units are land use and land cover (Anderson et al. 1976) and park specific map units. The map unit for lakes is by far the largest in area (>53,000 h), which is one of the land cover map units.

The greatest number of hectares mapped for vegetated map units is the Quaking Aspen-Paper Birch Forest (>21,000 h, AB), the Spruce Fir-Aspen Forest (>12,000 h, SFA), and the White Pine-Red Pine-Quaking Aspen-Paper Birch Forest (>9500 h, WRPA). These map units are each mapped at the alliance level within the USNVC, each with more than one association. WRPA, to reiterate, is also mapped as an aggregate of other map units (the AB map unit being one of them). The map units fall within 3 forested ecological groups: Boreal Hardwood Forests, Northern Spruce - Fir (Hardwood) Forests, and Northern Pine (Hardwood) Forests. The high numbers of hectares reflect the influence of natural events such as periodic forest fires and human impacts of logging on the forest ecosystem, especially the Quaking Aspen-Paper Birch Forest, which occurs as fairly young forest stands outside the park.

The map units with the largest polygon areas are in the Rat Root River Peatland: Black Spruce Bog (BSB) and Tamarack Scrub Poor Fen (TS). Although few in number (25 and 9 polygons respectively) these polygons range from an average of >30 h for BSB to 19 h for TF. Average polygon size drops sharply, to 9 h or less for all other vegetated map units.

Although each polygon is small in area (2.1 h average), the highest of number of polygons (> 5,500) are map units within the Treed Rock Barrens ecological group. Map units Boreal Pine Rocky Woodland (2 phases; JPW and JPM), Jack Pine/Lichen Rocky Barrens (JPL), Mixed Aspen Rocky Woodland (ABW), and Northern Pin Oak-Bur Oak- (Jack Pine) Rocky Woodland (3 phases; OW, JPOM, MPHW) make up the majority of this group. The associations recognized by these map units are confined to ridge tops and slopes where there is exposed bedrock.

Relatively rare in both number of polygons and in area are the map units Paper Birch/Fir Forest (PB) and Northern Bur Oak Mesic Forest (BO). PB occurs only near Deer Point Islands in the park. BO is most common on islands and peninsulas of Kabetogama Lake.

Table 6. Area Report for the Voyageurs National Park Vegetation Map.

Map Unit Code	Map Unit Name	Polygons	Hectares	Ave (h)	Acres	Ave (a)
Natural/Semi-natural Vegetation Map Units						
Bogs		563	3,427	6	8,468	15
Treed Bogs		25	761	30	1,879	75
BSB	Black Spruce Bog	25	761	30	1,879	75
Shrub Bogs		538	2,666	5	6,589	12
LBC	Black Spruce/Leatherleaf Semi-treed Bog	212	1,703	8	4,208	20
LB	Leatherleaf Bog	297	892	3	2,205	7
BBX	Beaver Basin Break-up Mosaic	29	71	2	176	6
Northern Shrub and Graminoid Fens		202	939	5	2,320	11
Shrub Fens		194	874	5	2,159	11
BBSF	Bog Birch-Willow Shore Fen	51	238	5	588	12
LSF	Leatherleaf-Sweet Gale Shore Fen	134	464	3	1,146	9
TF	Tamarack Scrub Poor Fen	9	172	19	425	47
Graminoid Fens		8	65	8	161	20
SPF	Northern Sedge Poor Fen	8	65	8	161	20
Wet Meadows		2,487	5,236	2	12,938	5
BJ	Canada Bluejoint Eastern Meadow	475	752	2	1,858	4
SMX	Wet Meadow/Fen Mosaic/Complex	2,012	4,484	2	11,080	6
Marshes		2,342	4,807	2	11,877	5
Emergent Marshes		1,223	2,605	2	6,436	5
PM	Eastern Reed Marsh	8	4	0	9	1
BM	Freshwater Bulrush Marsh	6	7	1	18	3
CM	Midwest Cattail Deep Marsh	212	475	2	1,173	6
WRM	Wild Rice Marsh	38	267	7	661	17
DMX	Deep Marsh Mosaic/Complex	959	1,852	2	4,575	5
Rooted and Floating Aquatic Marshes		1,119	2,202	2	5,441	5
PW	Midwest Pondweed Submerged Aquatic Wetland	669	1,223	2	3,023	5
WL	Northern Water Lily Aquatic Wetland	450	979	2	2,418	5
Northern Conifer and Hardwood Swamps		3,815	9,869	3	24,388	6
Rich Hardwood Swamps		1,858	3,507	2	8,665	5
BA	Black Ash-Mixed Hardwood Swamp	1,586	2,677	2	6,616	4
WCBA	White Cedar-Black Ash Swamp	272	829	3	2,049	8
Rich Conifer Swamps		1,029	2,488	2	6,148	6
BSAS	Black Spruce/Alder Rich Swamp	536	707	1	1,748	3
TA	Northern Tamarack Rich Swamp	255	705	3	1,743	7

Map Unit Code	Map Unit Name	Polygons	Hectares	Ave (h)	Acres	Ave (a)
WCS	White Cedar-(Mixed Conifer)/Alder Swamp (rich soil phase)	214	1,011	5	2,499	12
WCT	White Cedar-(Mixed Conifer)/Alder Swamp (peatland phase)	24	64	3	158	7
Poor Conifer Swamps		928	3,875	4	9,575	10
BSL	Black Spruce/Labrador Tea Poor Swamp (evergreen phase)	704	2,937	4	7,257	10
BST	Black Spruce/Labrador Tea Poor Swamp (mixed phase)	224	938	4	2,318	10
Northern Shrub Swamps		1,857	3,412	2	8,431	5
DS	Dogwood-Pussy Willow Swamp	262	587	2	1,450	6
AS	Speckled Alder Swamp	1,595	2,825	2	6,981	4
Rock Barrens		6,294	13,462	2	33,266	5
Treed Rock Barrens		5,583	11,829	2	29,230	5
JPW	Boreal Pine Rocky Woodland (jack pine phase)	1,087	2,118	2	5,233	5
JPM	Boreal Pine Rocky Woodland (mixed pine phase)	1,774	3,351	2	8,280	5
JPL	Jack Pine/Lichen Rocky Barrens	57	84	1	208	4
ABW	Mixed Aspen Rocky Woodland	856	1,659	2	4,099	5
OW	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (deciduous phase)	303	827	3	2,044	7
JPOM	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (jack pine-oak phase)	34	77	2	190	6
MPHW	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (mixed pine-oak phase)	1,472	3,713	3	9,176	6
Shrub and Herb Rock Barrens		711	1,633	2	4,036	6
UBS	Boreal Hazelnut-Serviceberry Rocky Shrubland	598	1,518	3	3,750	6
MGF	Poverty Grass Granite Barrens	113	116	1	286	3
Northern White Cedar-(Hardwood) Forests		708	1,498	2	3,702	5
WCU	White Cedar-Boreal Conifer Mesic Forest	324	488	2	1,207	4
WCA	White Cedar-Yellow Birch Forest	384	1,010	3	2,496	6
Northern Pine-(Hardwood) Forests		4,044	19,240	5	47,544	12
JPAX	Jack Pine-Aspen Forest Mosaic	715	4,592	6	11,348	16
JPF	Jack Pine/Balsam Fir Forest	909	2,502	3	6,183	7
WRPA	White Pine-Red Pine-Quaking Aspen-Paper Birch Forest	1,486	9,823	7	24,274	16
RP	Red Pine/Blueberry Dry Forest	289	594	2	1,468	5
WP	White Pine/Mountain Maple Mesic Forest	645	1,728	3	4,271	7
Northern Spruce-Fir-(Hardwood) Forests		4,222	14,734	3	36,408	9
SFA	Spruce-Fir-Aspen Forest	2,649	12,225	5	30,209	11
BSF	Black Spruce/Feathermoss Forest	406	551	1	1,360	3
SF	Spruce-Fir/Mountain Maple Forest	1,167	1,958	2	4,838	4
Boreal Hardwood Forests		4,626	24,873	5	61,462	13
AB	Quaking Aspen-Paper Birch Forest	3,361	21,696	6	53,613	16
PB	Paper Birch/Fir Forest	4	21	5	52	13
AL	Trembling Aspen-Balsam Poplar Lowland Forest	1,261	3,155	3	7,797	6
Northern Hardwood Forests		83	156	2	384	5
BO	Northern Bur Oak Mesic Forest	83	156	2	384	5

Map Unit Code	Map Unit Name	Polygons	Hectares	Ave (h)	Acres	Ave (a)
Planted/Cultivated, Land Use/Land Cover, and Park Specific Map Units						
Planted/Cultivated Vegetation (USNVC)		88	318	4	786	9
EP	Evergreen Plantation	4	4	1	10	2
PGCH	Perennial Grass Crops (hay, pastureland)	39	164	4	406	10
PGCS	Perennial Grass Crops with Sparse Shrubs (hay, pastureland)	45	150	3	370	8
Land Use/Land Cover (USGS - Anderson Level II)		385	54,559	142	134,819	350
Developed Lands		335	1,115	3	2,755	8
ACP	Cropland and Pasture	31	200	6	494	16
ARB	Other Agricultural Land	58	78	1	192	3
BLQ	Strip Mines, Quarries, and Gravel Pits	16	74	5	184	11
UC	Commercial and Services	47	210	4	519	11
UR	Residential	179	269	2	664	4
UT	Transportation, Communications, and Utilities	4	284	71	702	175
Lakes and Streams		50	53,445	1,069	132,064	2,641
WLK	Lakes (>16 h)	40	53,347	1,334	131,824	3,296
WS	Streams and Canals	10	97	10	240	24
Small Islands and Natural Ponds (Park Specific)		1,125	357	0	882	1
Small Islands (.01 - .05 h)		1,052	174	0	431	0
SIG	Small Island with Grass	11	1	0	3	0
SIR	Small Island with Rock	58	6	0	14	0
SIS	Small Island with Shrubs	128	16	0	39	0
SIT	Small Island with Trees	855	152	0	375	0
Small Natural Ponds (<10% vegetated)		73	183	3	451	6
WBP*	Water-Beaver Pond	52	70	1	173	3
WNP	Water-Natural Pond (<16 h)	21	113	5	279	13
Totals		**Polygons**	**Hectares**	**Ave (h)**	**Acres**	**Ave (a)**
All Map Units		**32,841**	**156,886**	**5**	**387,674**	**12**
Natural/Semi-natural Vegetation Map Units		**31,243**	**101,652**	**3**	**251,187**	**8**
Planted/Cultivated, Land Use/Land Cover, and Park Specific Map Units		**1,598**	**55,234**	**35**	**136,487**	**85**

* The Water-Beaver Pond Map Unit (WBP) does not include all beaver ponds present, but only those that appeared on the aerial photographs to have <10% of the surface area covered with vegetation. Many other beaver ponds were mapped under various vegetated map units, such as BBX, BJ, DMX, SMX, PW, WL, etc.

More than 1200 h of the Midwest Pondweed Submerged Aquatic Wetland Map Unit (PW) were mapped. However, some polygons of the Water-Beaver Pond Map Unit (WBP) and the Water-Natural Pond Map Unit (WNP), because of limitations in seeing submergent vegetation on CIR aerial photographs, may indeed have >10% vegetation. In such cases, these polygons would best be described within the Midwest Pondweed Submerged Aquatic Wetland Association of the USNVC (see Appendix F).

3.6 Accuracy Assessment

Forty-one map units and 4 map unit groups were assessed for accuracy. The 4 map unit groups were map units representing phases of individual vegetation associations. For example, BSL and BST represent the evergreen and mixed phases of the Black Spruce / Labrador Tea Poor Swamp Association and were assessed together because they represent a single association.

The overall thematic accuracy is 82.4% (Appendix D). For producers' accuracy, 29 of the 45 units (64%) reached at least 80% accuracy. Another 13 units fell below 80% accuracy. However, 80% is included within the confidence interval. Thus, 42 of the 45 units (93%) reached 80% accuracy when the confidence interval is taken into account. Three map units did not meet the Program's goal for producers' accuracy: the Quaking Aspen-Paper Birch Forest (AB, 65% with confidence interval 52-77%), the Spruce-Fir-Aspen Forest (SFA, 67% with confidence interval 54-79%), and the Northern Water Lily Aquatic Wetland (WL, 46% with confidence interval 31-61%).

For users' accuracy, 30 of the 45 units (67%) also reached at least 80% accuracy. Another 14 units fell below 80% accuracy. However, 80%is included within the confidence interval. Thus, 44 of 45 units (98%) reached 80% when the confidence interval is taken into account. One map unit did not meet the Program's goal for users' accuracy: Midwest Pondweed Submerged Aquatic Wetland (PW, 44% with confidence interval 27-62%).

Consideration was given to combining map units that did not meet 80% accuracy. However, it seems more useful to keep the map units separate and explain the errors rather than combine map units together. For example, producers' and users' accuracy for the Trembling Aspen-Balsam Poplar Lowland Forest Map Unit (AL) fell below 80% because it was more difficult to map than expected. This map unit grades into the Quaking Aspen-Paper Birch Forest Map Unit (AB) and other upland forest map units with similar signatures. More than 3,000 h and >1,000 polygons of AL have been mapped. Collapsing AL into AB would improve the accuracy assessment result, but the user would not know of the existence of AL, albeit with a lower degree of confidence.

Table 7 presents results of the accuracy assessment for the map units. The comments column reports the percent of polygons mapped in agreement with the accuracy assessment calls, and reports the types of errors. Nearly all errors occurred when a polygon was mapped as an association very similar to the accuracy assessment call. Many of these errors were related to different estimates of percent cover between the photo interpreter and ground crew (see Comments column in Table 7). The photo interpreter sees canopy crowns at a relatively small scale but over a relatively large area, and the field crew sees the canopy over a relatively small area. These different perspectives frequently lead to different estimates of percent cover, which in turn leads to differing conclusions on determining the vegetation type. When judging canopy cover, it is difficult to say which perspective provides the most accurate cover estimates. This is particularly true for conical crowned species, whose canopy is often widest near the ground. Problems with cover classes are also magnified by the overall structure of the classification system, which depends on percent cover to break forest from woodland. In addition, the finest levels of the classification depend on percent cover of individual species in the lower strata to separate associations from one another. The ability to discriminate vegetation types from aerial photographs using these kinds of criteria can be challenging.

Table 7. Summary of accuracy assessment results of the vegetation spatial database coverage for Voyageurs National Park and environs.

MAP UNIT CODE	MAP UNIT NAME	CONFIDENCE INTERVAL PRODUCER'S/ USERS	COMMENTS Producers' accuracy (errors of omission) is the probability that the map actually represents what was found on the ground. Users' accuracy (errors of commission) is the probability that an accuracy assessment point has been mapped correctly. Producers or users' accuracy is considered acceptable when 80% falls within the confidence interval. Errors are explained in the Comment Section.
Bogs			
Treed Bogs			
BSB	Black Spruce Bog	85-105% 98-103%	95% of the polygons identified by the accuracy assessment (aa) team as Black Spruce Bog (2485) were mapped correctly as BSB (producers' accuracy). An errors occurred when a polygon was mapped as BSL / BST. 100% of the polygons mapped as BSB were identified as Black Spruce Bog (2485) by the aa team (users' accuracy).
Shrub Bogs			
LBC	Black Spruce/Leatherleaf Semi-treed Bog	74-101% 60-90%	88% of the polygons identified by the aa team as Black Spruce / Leatherleaf Semi-treed Bog (5218) were mapped correctly as LBC (producers' accuracy). Errors occurred when polygons were mapped as LSF (2 errors) and BSAS (1 error). 75% of the polygons mapped as LBC were identified as Black Spruce / Leatherleaf Semi-treed Bog (5218) by the aa team (users' accuracy). Errors occurred when a polygon was mapped as BSL / BST (3 errors) or LB (4 errors).
LB	Leatherleaf Bog	58-88% 71-98%	73% of the polygons identified by the aa team as Leatherleaf Bog (2498) were mapped correctly as LB (producers' accuracy). Errors occurred when a polygon was mapped as LBC (4 errors), BBSF (2 errors), AS (1 error), and SMX (1 error). 85% of the polygons mapped as LB were identified as Leatherleaf Bog (2498) by the aa team (users' accuracy). Errors occurred when polygons were mapped as AS (1error), BSAS (1 error), or when identified as Northern Sedge Wet Meadow (2257) by the aa team. Northern Sedge Wet Meadow should have been mapped as BBX or SMX.
BBX	Beaver Basin Break-up Mosaic	75-125% 75-125%	100% of the polygons identified by the aa team as Northern Sedge Wet Meadow (2257) were mapped correctly as BBX (producers' accuracy). 100% of the polygons mapped as BBX were identified as Northern Sedge Wet Meadow (2257) by the aa team (users accuracy).

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Northern Shrub and Graminoid Fens			
Shrub Fens			
BBSF	Bog Birch-Willow Shore Fen	84-106% 67-98%	95% of the polygons identified by the aa team as Bog Birch - Willow Shore Fen (5227) were mapped correctly as BBSF (producers' accuracy). An error occurred when a polygon was mapped as DS (1 error). 83% of the polygons mapped as BBSF were identified as Bob Birch - Willow Shore Fen (5227) by the aa team (users' accuracy). Errors occurred when polygons were mapped as LB (2 errors), BSL / BST (1 error), and AS (1error).
LSF	Leatherleaf-Sweet Gale Shore Fen	78 – 103% 78 – 103%	90% of the polygons identified by the aa team as Leatherleaf - Sweet Gale Shore Fen (5228) were mapped correctly as LSF (producers' accuracy). Errors occurred when polygons were mapped as SMX (2 errors). 90% of the polygons mapped as LSF were identified as Leatherleaf - Sweet Gale Shore Fen (5228) by the aa team (users' accuracy). Errors occurred when polygons were mapped as LBC (2 errors).
TF	Tamarack Scrub Poor Fen	95-105% 61-105%	100% of the polygons identified by the aa team as Tamarack Scrub Poor Fen (5226) were mapped correctly as TF (producers ' accuracy). 83% of the polygons mapped as TF were identified as Tamarack Scrub Poor Fen (5226) by the aa team (users' accuracy). Errors occurred when polygons were mapped as WCS / WCT (2 errors).
Graminoid Fens			
SPF	Northern Sedge Poor Fen	94-106% 94-106%	100% of the polygons identified by the aa team as Northern Sedge Poor Fen (2265) were mapped correctly as SPF (producers' accuracy). 100% of the polygons mapped as SPF were identified as Northern Sedge Poor Fen (2265) by the aa team (users' accuracy).
Wet Meadows			
BJ	Canada Bluejoint Eastern Meadow	86-105% 56-86%	96% of the polygons identified by the aa team as Canada Bluejoint Eastern Meadow (5174) were mapped correctly as BJ (producers' accuracy). Error occurred when a polygon was mapped as DS (1 error). 71% of the polygons mapped as BJ were identified as Canada Bluejoint Eastern Meadow (5174) by the aa team (users accuracy). Errors occurred when polygons were mapped as BJ but identified by the aa team as Northern Sedge Wet Meadow (2257; 7 errors), as Wiregrass Shore Fen (5229; 1 error), and when mapped as WL (1 error).

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SMX	Wet Meadow/Fen Mosaic/Complex	55-80% 64-89%	67% of the polygons identified by the aa team as one of the associations of SMX (5174, 2257, 4141, 2233, 5229) were mapped correctly as SMX (producers' accuracy). Errors occurred when polygons were mapped as BJ (8 errors), CM (1 error), DS (1 error), LB (2 errors), PW (1 error), and WL (2 errors). 76% of the polygons mapped as SMX were identified as one of the associations of SMX by the aa team (users' accuracy). Errors occurred when polygons were mapped as DS (1 error), LB (1 error), LSF (1 error), and WL (5 errors).
Marshes			
Emergent Marshes			
PM	Eastern Reed Marsh	27-107% 88-113%	67% of the polygons identified by the aa team as Eastern Reed Marsh (4141) were mapped correctly as PM (producers' accuracy). Errors occurred when polygons were mapped as BJ (2 errors). 100% of the polygons mapped as PM were identified as Eastern Reed Marsh (4141) by the aa team (users' accuracy).
BM	Freshwater Bulrush Marsh	-28-95% -28-95%	33% of the polygons identified by the aa team as Freshwater Bulrush Marsh (2225) were mapped correctly as BM (producers' accuracy). Errors occurred when polygons were mapped as WRM (2 errors). 33% of the polygons mapped as BM were identified as Freshwater Bulrush Marsh (2225) by the aa team (users' accuracy). Errors occurred when polygons were mapped as PM (2 errors).
CM	Midwest Cattail Deep Marsh	98-102% 86-105%	100% of the polygons identified by the aa team as Midwest Cattail Deep Marsh (2233) were mapped correctly as CM (producers' accuracy). 95% if the polygons mapped as CM were identified as Midwest Cattail Deep Marsh (2233) by the aa team (users' accuracy). Error occurred when a polygon was mapped as LSF (1 error).
WRM	Wild Rice Marsh	72-104% 50-87%	88% of the polygons identified by the aa team as Wild Rice Marsh (2382) were mapped correctly as WRM (producers' accuracy). Errors occurred when polygons were mapped as WL (1error) and PW (1 error). 68% of the polygons mapped as WRM were identified as Wild Rice Marsh (2382) by the aa team (users' accuracy). Errors occurred when polygons were mapped as BM (2 errors), PW (4 errors), and WL (1 error).

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DMX	Deep Marsh Mosaic/Complex	90-103% 98-102%	97% of the polygons identified by the aa team as one of the associations of DMX (4141, 2225, 3344, 2382, 5258, 2562, 2282) were mapped correctly as DMX (producers' accuracy). An error occurred when a polygon was mapped as CM. 100% of the polygons mapped as DMX were identified as one of the associations within DMX by the aa team (users accuracy).
Rooted and Floating Aquatic Marshes			
PW	Midwest Pondweed Submerged Aquatic Wetland	49-92% 27-62%	71% of the polygons identified by the aa team as Midwest Pondweed Submerged Aquatic Wetland (2282) were mapped correctly as PW (producers' accuracy). Errors occurred when polygons were mapped as WRM (4 errors), and WL (1 error). 44% of the polygons mapped as PW were identified as Midwest Pondweed Submerged Aquatic Wetland (2282) by the aa team (users accuracy). Errors occurred when polygons were mapped as WL (13 errors) and WRM (1 error). 1 error occurred when a polygon was mapped as PW but was identified by the aa team as Northern Sedge Wet Meadow (2257).
WL	Northern Water Lily Aquatic Wetland	31-61% 64-97%	46% of the polygons identified by the aa team as Northern Water Lily Aquatic Wetland (2562) were mapped correctly as WL (producers' accuracy). Errors occurred when polygons were mapped as PW (13 errors), SMX (5 errors), WRM (1 error), and BJ (1error). 81% of the polygons mapped as WL were identified as Northern Water Lily Aquatic Wetland (2562) by the aa team (users' accuracy). Errors occurred when polygons were mapped as PW (1 error) and WRM (1 error). 2 polygons were mapped as WL but were identified by the aa team as Northern Sedge Wet Meadow (2257).
Northern Conifer and Hardwood Swamps			
Rich Hardwood Swamps			
BA	Black Ash-Mixed Hardwood Swamp	56-86% 75-101%	71% of the polygons identified by the aa team as Black Ash - Mixed Hardwood Swamp (2105) were mapped correctly as BA (producers' accuracy). Errors occurred when polygons were mapped as AB (1 error), AL (1error), BO (1error), SFA (1 error), and WCBA (5 errors). 88% of the polygons mapped as BA were identified as Black Ash - Mixed Hardwood Swamp (2105) by the aa team. Errors occurred when polygons were mapped as AL (1 error), BO (1error), and WCBA (1 error).

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WCBA	White Cedar-Black Ash Swamp	67-96% 64-93%	81% of the polygons identified by the aa team as White Cedar - Black Ash Swamp (5165) were mapped correctly as WCBA (producers' accuracy). Errors occurred when polygons were mapped as BA (1 error), WCA (1 error), and WCS / WCT (3 errors). 79% of the polygons mapped as WCBA were identified as White Cedar - Black Ash Swamp (5165) by the aa team (users' accuracy). Errors occurred when polygons were mapped as BA (5 errors), and AS (1 error).
Rich Conifer Swamps			
BSAS	Black Spruce/Alder Rich Swamp	59-94% 46-82%	76% of the polygons identified by the aa team as Black Spruce / Alder Rich Swamp (2452) were mapped correctly as BSAS (producers' accuracy). Errors occurred when polygons were mapped as BSL / BST (3 errors), LB (1 error), TA (1 error). 64% of the polygons mapped as BSAS were identified as Black Spruce / Alder Rich Swamp (2452) by the aa team (users' accuracy). Errors occurred when polygons were mapped as BSL / BST (4 errors), LBC (1 error), and WCS / WCT (4 errors).
TA	Northern Tamarack Rich Swamp	94-102% 72-90%	98% of the polygons identified by the aa team as Northern Tamarack Rich Swamp (2471) were mapped correctly as TA (producers' accuracy). Error occurred when a polygon was mapped a WCS / WCT (1 error). 81% of the polygons mapped as TA were identified as Northern Tamarack Rich Swamp (2471) by the aa team (users' accuracy). Errors occurred when polygons were mapped as BSL / BST (10 errors), BSAS (1 error), and AS (1 error).
WCS / WCT	White Cedar-(Mixed Conifer)/Alder Swamp (rich soil phase and peatland phase)	55-82% 71-96%	68% of the polygons identified by the aa team as White Cedar - (Mixed Conifer)/ Alder Swamp (2456) were mapped correctly as WCS or WCT (producers accuracy). Errors occurred when polygons were mapped as BSAS (4 errors), BSL / BST (4 errors), TF (2 errors), and WCU (2 errors). 84% of the polygons mapped as WCS / WCT were identified as White Cedar - (Mixed Conifer)/Alder Swamp (2456) by the aa team (users' accuracy). Errors occurred when polygons were mapped as WCU (1 error), WCS / WCT (3 errors), TA (1 error).

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Poor Conifer Swamps			
BSL / BST	Black Spruce/Labrador Tea Poor Swamp (evergreen phase & mixed phase)	69-85%	77% of the polygons identified by the aa team as Black Spruce /Labrador Tea Poor Swamp (2454) were mapped correctly as BSL or BST (producers' accuracy). Errors occurred when polygons were mapped as BBSF (1 error), BSAS (4 errors), BSF (1 error), LBC (3 errors), and TA (10 errors).
		82-96%	89% of the polygons mapped as BSL / BST were identified as Black Spruce /Labrador Tea Poor Swamp (2454) by the aa team (users' accuracy). Errors occurred when polygons were mapped as BSAS (3 errors), BSB (1 error), and WCS / WCT (4 errors).
Northern Shrub Swamps			
DS	Dogwood-Pussy Willow Swamp	72-98%	85% of the polygons identified by the aa team as Dogwood - Pussy Willow Swamp (2186) were mapped correctly as DS (producers' accuracy). Errors occurred when polygons were mapped as AS (2 errors), SMX (1 error), and UBS (1 error).
		68-96%	82% of the polygons mapped as DS were identified as Dogwood - Pussy Willow Swamp (2186) by the aa team (users' accuracy). Errors occurred when polygons were mapped as AS (2 errors), BBSF (1 error), and BJ (1 error), and when 1 polygon was mapped as DS but was identified by the aa team as Northern Sedge Wet Meadow (2257).
AS	Speckled Alder Swamp	67-92%	79% of the polygons identified by the aa team as Speckled Alder Swamp (2381) were mapped correctly as AS (producers' accuracy). Errors occurred when polygons were mapped as AL (1 error), BBSF (1 error), DS (2 errors), LB (1 error), TA (1 error), WCBA (1 error).
		76-99%	87% of the polygons mapped as AS were identified as Speckled Alder Swamp (2381) by the aa team (users' accuracy). Errors occurred when polygons were mapped as DS (2 errors), LB (1 error), and UBS (1 error).

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Rock Barrens			
Treed Rock Barrens			
JPW / JPM	Boreal Pine Rocky Woodland (jack pine phase and mixed pine phase)	61-83% 99-101%	72% of the polygons identified by the aa team as Boreal Pine Rocky Woodland (2483) were mapped correctly as JPW or JPM (producers' accuracy). Errors occurred when polygons were mapped as BSF (1 error), JPL (1error), JPAX (1 error), MPHW (9 errors), and SFA (2 errors). 100% of the polygons mapped as JPW / JPM were identified as Boreal Pine Rocky Woodland (2483) by the aa team (users' accuracy).
JPL	Jack Pine/Lichen Rocky Barrens	97-103% 68-101%	100% of the polygons identified by the aa team as Jack Pine / Lichen Rocky Barrens (2491) were mapped correctly as JPL (producers' accuracy). 84% of the polygons mapped as JPL were identified as Jack Pine / Lichen Rocky Barrens (2483) by the aa team (users' accuracy). Errors occurred when polygons were mapped as ABW (2 errors), and JPW / JPM (1 error).
ABW	Mixed Aspen Rocky Woodland	61-101% 51-85%	85% of the polygons identified by the aa team as Mixed Aspen Rocky Woodland (2487) were mapped correctly as ABW (producers' accuracy). Errors occurred when polygons were mapped as JPL (2 errors), and MPHW (1 error). 68% of the polygons mapped as ABW were identified as Mixed Aspen Rocky Woodland (2487) by the aa team (users' accuracy). Errors occurred when polygons were mapped as AB (5 errors), MPHW (1 error), and SFA (2 errors).
JPOM / MPHW / OW	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (jack pine-oak phase, mixed pine-oak phase, and deciduous phase)	96-102% 79-92%	99% of the polygons identified by the aa team as Northern Pin Oak-Bur Oak - (Jack Pine) Rocky Woodland (5246) were mapped correctly as JPOM, MPHW, or OW (producers' accuracy). Error occurred when a polygon was mapped as ABW (1 error). 86% of the polygons mapped as JPOM, MPHW, or OW were identified as Northern Pin Oak-Bur Oak - (Jack Pine) Rocky Woodland (5246) by the aa team (users' accuracy). Errors occurred when polygons were mapped as AB (1 error), ABW (1error), and JPW / JPM (9 errors).

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Shrub and Herb Rock Barrens			
UBS	Boreal Hazelnut-Serviceberry Rocky Shrubland	80-101% 76-99%	90% of the polygons identified by the aa team as Boreal Hazelnut - Serviceberry Rocky Shrubland (5197) were mapped correctly as UBS (producers' accuracy). Errors occurred when polygons were mapped as AS (1 error), AL (1 error), and SFA (1 error). 88% of the polygons mapped as UBS were identified as Boreal Hazelnut - Serviceberry Rocky Shrubland (5197) by the aa team (users' accuracy). Errors occurred when polygons were mapped as AB (1 error), AL (1 error), BO (1 error), and DS (1 error).
MGF	Poverty Grass Granite Barrens	83-117% 83-117%	100% of the polygons identified by the aa team as Poverty Grass Granite Barrens (5157) were mapped correctly as MGF (producers' accuracy). 100% of the polygons mapped as MGF were identified as Poverty Grass Granite Barrens (5157) by the aa team (users' accuracy).
Northern White Cedar-(Hardwood) Forests			
WCU	White Cedar-Boreal Conifer Mesic Forest	75-101% 76-101%	88% of the polygons identified by the aa team as White Cedar - Boreal Conifer Mesic Forest (2449) were mapped correctly as WCU (producers' accuracy). Errors occurred when polygons were mapped as WCS, WCT (1 error), and WCA (2 errors). 88% of the polygons mapped as WCU were identified as White Cedar - Boreal Conifer Mesic Forest (2449) by the aa team (users' accuracy). Errors occurred when polygons were mapped as WCS / WCT (2 errors), and WRM (1 error).
WCA	White Cedar-Yellow Birch Forest	84-103% 67-92%	93% of the polygons identified by the aa team as White Cedar – Yellow Birch Forest (5165) were mapped correctly as WCA (producers' accuracy). Errors occurred when polygons were mapped as AL (1 error), and WP (1 error). 79% of the polygons mapped as WCA were identified as White Cedar – Yellow Birch Forest (5165) by the aa team (users' accuracy). Errors occurred when polygons were mapped as AB (1 error), AL (1 error), SFA (2 errors), WCT / WCS (1 error), and WCU (2 errors).

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Northern Pine-(Hardwood) Forests			
JPAX	Jack Pine-Aspen Forest Mosaic	66-94% 66-94%	83% of the polygons identified by the aa team as associations included in JPAX (2437, 2467, 2466, 2518) were mapped correctly as JPAX (producers' accuracy). Errors occurred when polygons were mapped as BSF (1 error), JPF (3 errors), and WRPA (1 error). 80% of the polygons mapped as JPAX were identified by the aa team as associations included in JPAX. Errors occurred when polygons were mapped as JPW / JPM (1 error), and SFA (5 errors).
JPF	Jack Pine/Balsam Fir Forest	82-103% 65-92%	93% of the polygons identified by the aa team as Jack Pine / Balsam Fir Forest (2437) were mapped correctly as JPF (producers' accuracy). Errors occurred when polygons were mapped as RP (1 error), and AB (1 error). 78% of the polygons mapped as JPF were identified by the aa team as Jack Pine / Balsam Fir Forest (2437). Errors occurred when polygons were mapped as BSF (3 errors), WP (3 errors) and when polygons were mapped as JPF but were identified by aa team as Jack Pine - Aspen / Bush Honeysuckle Forest (2518, 3 errors).
WRPA	White Pine-Red Pine-Quaking Aspen-Paper Birch Forest	74-96% 87-102%	85% of the polygons identified by the aa team as associations included in WRPA (2443, 2445, 2467, 2466, 2520, 2479) were mapped correctly as WRPA (producers' accuracy). Errors occurred when polygons were mapped as WP (2 errors), AB (2 errors), RP (1 error), and WCU (1 error). 94% of the polygons mapped as WRPA were identified by the aa team as associations included in WRPA. Errors occurred when polygons were mapped as JPW/JPM (1 error) and JPAX (1error).
RP	Red Pine/Blueberry Dry Forest	72-98% 76-101%	85% of the polygons identified by the aa team as Red Pine / Blueberry Dry Forest (2443) were mapped correctly as RP (producers' accuracy). Errors occurred when polygons were mapped as AB (1 error), and WP (3 errors). 88% of the polygons mapped as RP were identified by the aa team as Red Pine / Blueberry Dry Forest (2443). Errors occurred when polygons were mapped as JPF (1 error), WP (1 error) and WRPA (1 error).

MAP UNIT CODE	MAP UNIT NAME	CONFIDENCE INTERVAL PRODUCER'S/ USERS	COMMENTS Producers' accuracy (errors of omission) is the probability that the map actually represents what was found on the ground. Users' accuracy (errors of commission) is the probability that an accuracy assessment point has been mapped correctly. Producers or users' accuracy is considered acceptable when 80% falls within the confidence interval. Errors are explained in the Comment Section.
WP	White Pine/Mountain Maple Mesic Forest	77-101% 63-91%	89% of the polygons identified by the aa team as White Pine / Mountain Maple Mesic Forest (2445) were mapped correctly as WP (producers' accuracy). Errors occurred when polygons were mapped as JPF (1 error), SFA (1 error), and RP (1 error). 77% of the polygons mapped as WP were identified by the aa team as White Pine / Mountain Maple Mesic Forest (2445). Errors occurred when polygons were mapped as RP (3 errors), SFA (1 error), WCA (1 error), and WRPA when polygons were identified by aa team as pine-aspen mixed forest types (2479/2520, 2 errors).
Northern Spruce-Fir-(Hardwood) Forests			
SFA	Spruce-Fir-Aspen Forest	54-79% 59-83%	67% of the polygons identified by the aa team as Spruce - Fir - Aspen Forest (2475) or as Black Spruce - Aspen Forest (5116) were mapped correctly as SFA (producers' accuracy). Errors occurred when polygons were mapped as ABW (2 errors), AL (1 error), JPAX (5 errors), MPHW (1 error), SF (4 errors), WCA (2 errors) and WP (1 error). 71% of the polygons mapped as SFA were identified by the aa team as Spruce - Fir - Aspen Forest (2475) or as Black Spruce - Aspen Forest (5116). Errors occurred when polygons were mapped as AB (5 errors), AL (1 error), BA (1 error), BSF (1 error), JPW / JPM (2 errors), SF (1 error), UBS (1 error), WP (1error).
BSF	Black Spruce/Feathermoss Forest	65-93% 72-98%	79% of the polygons identified by the aa team as Black Spruce / Feathermoss Forest (2447) were mapped correctly as BSF (producers' accuracy). Errors occurred when polygons were mapped as JPF (3 errors), SF (2 errors), and SFA (1 error). 85% of the polygons mapped as BSF were identified by the aa team as Black Spruce / Feathermoss Forest (2447). Errors occurred when polygons were mapped as BSL / BST (1error), JPAX (1error), JPW / JPM (1 error), and SF (1 error).
SF	Spruce-Fir/Mountain Maple Forest	80-103% 64-93%	92% of the polygons identified by the aa team as Spruce Fir - Mountain Maple Forest (2446) or Balsam Fir - Paper Birch Forest (2474) were mapped correctly as SF (producers' accuracy). Errors occurred when polygons were mapped as BSF (1 error), and SFA (1 error). 79% of the polygons mapped as SF were identified by the aa team as Spruce Fir - Mountain Maple Forest (2446) or Balsam Fir - Paper Birch Forest (2474). Errors occurred when polygons were mapped as BSF (2 errors), and SFA (4 errors).

MAP UNIT CODE	MAP UNIT NAME	CONFIDENCE INTERVAL PRODUCER'S/ USERS	COMMENTS Producers' accuracy (errors of omission) is the probability that the map actually represents what was found on the ground. Users' accuracy (errors of commission) is the probability that an accuracy assessment point has been mapped correctly. Producers or users' accuracy is considered acceptable when 80% falls within the confidence interval. Errors are explained in the Comment Section.
Boreal Hardwood Forests			
AB	Quaking Aspen-Paper Birch Forest	52-77% 72-95%	65% of the polygons identified by the aa team as Aspen - Birch / Boreal Conifer Forest (2466) or Aspen - Birch - Red maple Forest (2467) were mapped correctly as AB (producers' accuracy). Errors occurred when polygons were mapped as ABW (5 errors), AL (3 errors), BO (1 error), MPHW (1 error), SFA (5 errors), UBS (1 error), and WCA (1 error). 84% of the polygons mapped as JPF were identified by the aa team as Jack Pine / Balsam Fir Forest (2437). Errors occurred when polygons were mapped AL (1 error), BA (1 error), JPF (1 error), and RP (1 error). One polygon mapped as AB was identified by the aa team as White Pine - Aspen - Birch Forest (2479).
PB	Paper Birch/Fir Forest	41-119% 88-113%	80% of the polygons identified by the aa team as Paper Birch / Fir Forest (2463) were mapped correctly as JPF (producers' accuracy). An errors occurred when a polygon was mapped as AL (1 error). 100% of the polygons mapped as PB were identified by the aa team as Paper Birch / Fir Forest (2463
AL	Trembling Aspen-Balsam Poplar Lowland Forest	57-93% 44-81%	75% of the polygons identified by the aa team as were mapped correctly as AL (producers' accuracy). Errors occurred when polygons were mapped as AB (1 error), BA (1error), SFA (1 error), UBS (1 error), and WCA (1 error). 63% of the polygons mapped as AL were identified by the aa team as Trembling Aspen - Balsam Poplar Lowland Forest (5036). Errors occurred when polygons were mapped as AB (3 errors), AS (1 error) BA (1 error), WCBA (1 error).
Northern Hardwood Forests			
BO	Northern Bur Oak Mesic Forest	84-102% 84-102%	93% of the polygons identified by the aa team as Northern Bur Oak Mesic Forest (2072) were mapped correctly as BO (producers' accuracy). Errors occurred when polygons were mapped as BA (1 error), and UBS (1 error). 93% of the polygons mapped as BO were identified by the aa team as Northern Bur Oak Mesic Forest (2072). Errors occurred when polygons were mapped as AB (1 error), and BA (1 error).

3.7 Recommendations for Future Projects

Several ideas for improving the mapping process have surfaced as a result of the Voyageurs project. Improving the mapping process in ways suggested herein would save time and money, and provide for more accurate mapping.

Aerial Photographs

Having two sets of aerial photographs (fall 1995/1996 and fall 1988) for this mapping project provided invaluable information in distinguishing between several vegetation types and maximized the interpretation effort. Differences in phenological stages of the vegetation between the 2 photo sets allowed interpretation that would not have been possible if only one set was used. It is recommended that whenever possible, two sets of aerial photographs should be acquired.

Classification Development

It is highly recommended that a completed (or nearly completed) classification be in place before the actual interpretation begins. Ideally, mappers and ecologists should do field reconnaissance together so that a strong connection between mapping and classification is created from the beginning of the project. Plot sampling should begin early in the project, followed by analysis of the vegetation data before the mappers begin ground-truthing and interpretation of the aerial photographs. It is important that the mappers have written descriptions of the associations and a vegetation key during ground-truthing so that their understanding of the vegetation types can be related to the photo signatures. It is not only frustrating and time consuming to ground truth aerial photos and build map unit classifications when the types are not known or well-understood, but it also leads to incorrect mapping. Further, unnecessary time is spent mapping polygons that, in the end, turn out to be phases of associations. The Voyageurs project has 9 map units that fall into this phase category, which in turn represent 4 plant communities. What has not been discussed in this report is the 5 or 6 situations where map units have been collapsed together (performed globally in GIS), decisions made after the vegetation classification was better understood. It cannot be emphasized enough the extensive amount time that goes into map unit development, mapping convention, interpretive decisions, and even the map production when a good grasp of the vegetation communities is not well understood. Most importantly, lengthy explanations are needed to describe disparities between map units and associations because the two systems (classification and map unit) have used different approaches to describe the vegetation. No matter how clearly the linkages are described, the potential for confusion remains. The purpose for using the USNVC is to promote increased sharing, exchanging, and comparing of vegetation-related data among federal government agencies and other partners. This is greatly hindered when map units deviate from the USNVC.

Accuracy Assessment

Accuracy assessment forms need to be standardized throughout the mapping program. The data sheets need to include finer resolution of cover scales for species and for strata. Vegetation types are typically separated from one another based on percent cover, and the right information needs to be recorded so that the data sheets can be re-evaluated if necessary during the accuracy assessment analysis. For the Voyageurs project, several errors were discovered when cover estimates were incorrect for the vegetation types listed. However, for several other data sheets, the cover scales used were often too broad to evaluate whether the correct vegetation type had been selected.

Front-loading accuracy assessment is *not* recommended if at all possible. For Voyageurs, this led to two different approaches for fieldwork and caused confusion, controversy, and extra effort of everyone involved. The digital data is important to complete before the accuracy assessment teams work in the field so that a digital map of the polygons can be provided.

Better methodologies for selecting accuracy assessment points need to be developed. While stratified random selection may continue as the preferred approach, many other considerations need to be built into an automated program that is beyond the expertise of the mapping team. A statistician who understands logistical and spatial issues in addition to proper application of statistical methodologies should be available to every park. Further, a statistician could build the proper statistical programs for running analysis of the accuracy assessment data.

Reports and Formating

A standard format for reports is needed. The standard format should include tables, graphics, and appendices that are consistent throughout the program and are designed to present the information in a user-friendly way. In addition, the standard should include introductory material, a glossary, and a reference section so that all reports provide some of the basic information about the program.

GPS Data Collection

It is vital that all GPS reference data be collected in the same datum, North American Datum of 1983.

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Appendix A

Observation Points for the Voyageurs National Park Vegetation Mapping Project

(Location Map and Condensed Listing)

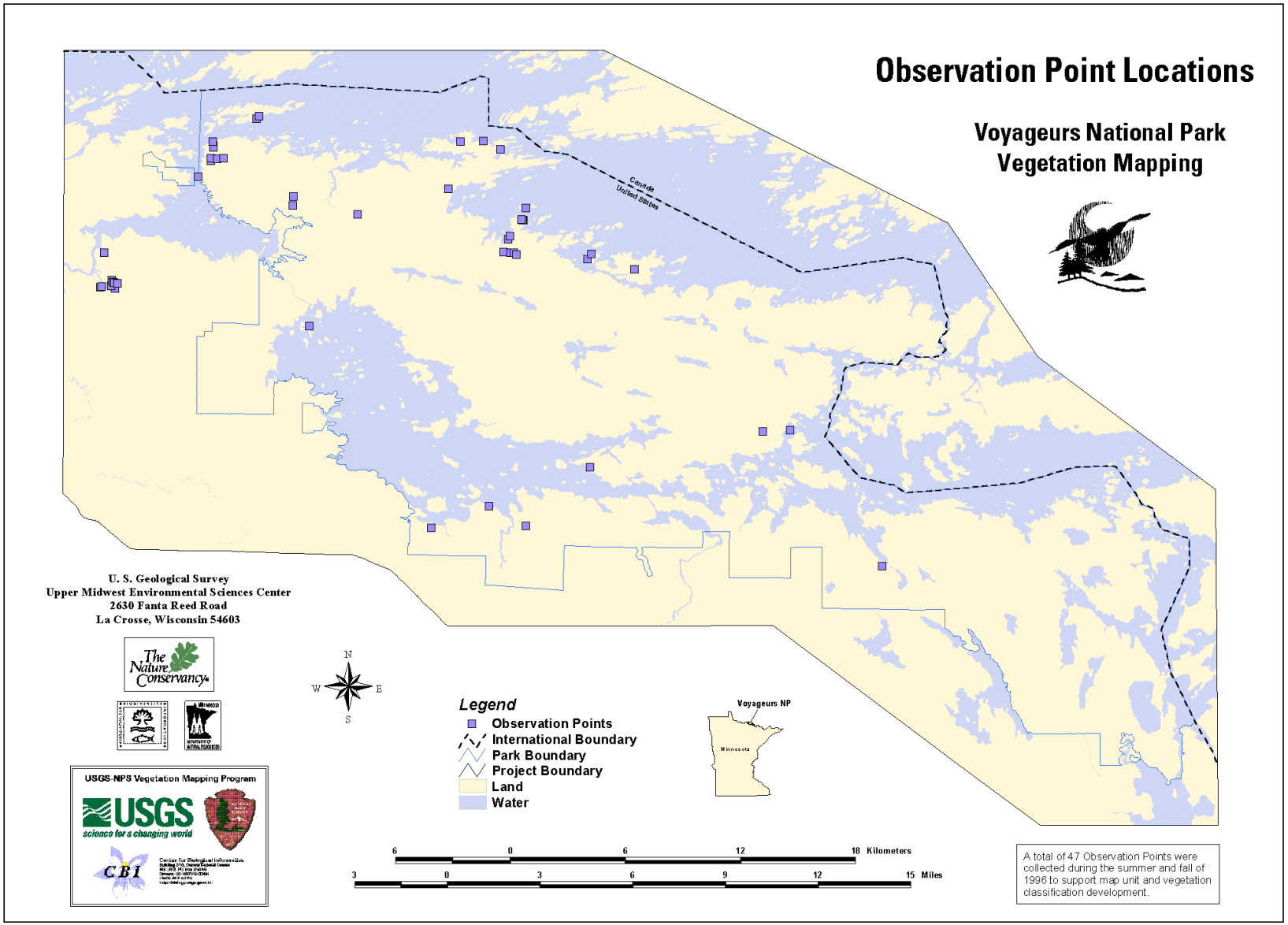

Figure 18. Locations of observations points collected by ecologist and mapping teams during 1996 field reconnaissance

Observation	Map Unit Code	Map Unit Description Name	Elcode
1	WP	White Pine/Mountain Maple Mesic Forest	CEGL002445
2	AS	Speckled Alder Swamp	CEGL002381
3	BSL	Black Spruce/Labrador Tea Poor Swamp (evergreen phase)	CEGL002454
4	BST	Black Spruce/Labrador Tea Poor Swamp (mixed phase)	CEGL002454
5	TA	Northern Tamarack Rich Swamp	CEGL002471
6	AS	Speckled Alder Swamp	CEGL002381
7	AL	Trembling Aspen-Balsam Poplar Lowland Forest	CEGL005036
8	SMX	Wet Meadow/Fen Mosaic/Complex	CEGL002257
9	LBC	Black Spruce/Leatherleaf Semi-treed Bog	CEGL005218
10	UBS	Boreal Hazelnut-Serviceberry Rocky Shrubland	CEGL005197
11	MPHW	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (mixed pine-oak phase)	CEGL005246
12	AL	Trembling Aspen-Balsam Poplar Lowland Forest	CEGL005036
13	WRPA	White Pine-Red Pine-Quaking Aspen-Birch Forest	CEGL002479
14	TA	Northern Tamarack Rich Swamp	CEGL002471
15	AB	Quaking Aspen-Paper Birch Forest	CEGL002467
16	BA	Black Ash-Mixed Hardwood Swamp	CEGL002105
17	OW	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (deciduous phase)	CEGL005246
18	JPAX	Jack Pine-Aspen Forest Mosaic	CEGL002518
19	JPF	Jack Pine/Balsam Fir Forest	CEGL002437
20	WP	White Pine/Mountain Maple Mesic Forest	CEGL002445
21	BSF	Black Spruce/Feathermoss Forest	CEGL002447
22	BSL	Black Spruce/Labrador Tea Poor Swamp (evergreen phase)	CEGL002454
23	JPF	Jack Pine/Balsam Fir Forest	CEGL002437
24	AB	Quaking Aspen-Paper Birch Forest	CEGL002466
25	SF	Spruce-Fire/Mountain Maple Forest	CEGL002446
26	JPOM	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (jack pine-oak phase)	CEGL005246
27	BSL	Black Spruce/Labrador Tea Poor Swamp (evergreen phase)	CEGL002454
28	BSAS	Black Spruce/Alder Rich Swamp	CEGL002452
29	WP	White Pine/Mountain Maple Mesic Forest	CEGL002445
30	OW	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (deciduous phase)	CEGL005246
31	RP	Red Pine/Blueberry Dry Forest	CEGL002443
32	BSF	Black Spruce/Feathermoss Forest	CEGL002447
33	BJ	Canada Bluejoint Eastern Marsh	CEGL005174
34	JPW	Boreal Pine Rocky Woodland (jack pine phase)	CEGL002483
35	WCU	White Cedar-Boreal Conifer Mesic Forest	CEGL002449
36	WCS	White Cedar-(mixed conifer)/Alder Swamp (rich soil phase)	CEGL002456
37	TA	Northern Tamarack Rich Swamp	CEGL002471
38	MPHW	Northern Pin Oak-Bur Oak-(Jack Pine) Rocky Woodland (mixed pine-oak phase)	CEGL005246
39	JPW	Boreal Pine Rocky Woodland (jack pine phase)	CEGL002483
40	ABW	Mixed Aspen Rocky Woodland	CEGL002487
41	JPW	Boreal Pine Rocky Woodland (jack pine phase)	CEGL002483
42	WCBA	White Cedar-Black Ash Swamp	CEGL005165
43	PB	Paper Birch/Fir Forest	CEGL002463
44	JPL	Jack Pine/Lichen Rocky Barrens	CEGL002491
45	DS	Dogwood-Pussy Willow Swamp	CEGL002186
46	BO	Northern Bur Oak Mesic Forest	CEGL002072
47	WCU	White Cedar-Boreal Conifer Mesic Forest	CEGL002449

Appendix B

Classification Matrix

(USNVC Vegetation Communities and Map Units)

How to use the classification matrix

The classification matrix is a separate spreadsheet. The matrix is designed to show the relationships between the USNVC vegetation associations and the map units used in the Voyageurs National Park mapping project. The associations are listed in rows and the map unit codes are listed in columns. Blue squares indicate a match or link between the associations and map units. In most instances, there is one blue square where a map unit links to an association. Thus, one blue square represents a one-to-one relationship between a given map unit and its corresponding vegetation association.

Some map units have more than one blue square in their columns. This means that map units sometimes include more than one association. For example, SF includes both the Balsam Fir-Paper Birch Forest and the Spruce-Fir/Mountain Maple Forest.

Some associations have more than one blue square in their rows. This means that some associations are mapped in more than one map unit. For example, the Black Spruce/Labrador Tea Poor Swamp was mapped using either BSL or BST. In this case, BSL and BST are phases of the association and were used to indicate either an evergreen or a mixed phase of the association.

Appendix C

Accuracy Assessment Forms

(1997 and 1998)

NATIONAL PARK VEGETATION MAPPING PROGRAM: OBSERVATION POINT FORM (1997)

IDENTIFIERS/LOCATORS

Plot Code_____ Polygon Code_____

Provisional Community Name_____

State ___ Park Name _____ Park Site Name _____

Quad Name_____ Quad Code_____

GPS file name_____ Field UTM X___ ___ ___ ___ ___ ___ m E Field UTM Y___ ___ ___ ___ ___ ___ ___ m N

please do not complete the following information when in the field
Corrected UTM X___ ___ ___ ___ ___ ___ m E Corrected UTM Y___ ___ ___ ___ ___ ___ ___ m N UTM Zone_____

Survey Date_____ Surveyors_____

ENVIRONMENTAL DESCRIPTION

Elevation _____ Slope _____ Aspect_____

Topographic Position

Landform

Cowardian System	Hydrologic Regime		Salinity Modifiers
___Upland	Non-Tidal		___Saltwater
___Riverine	___Permanently Flooded	___Saturated	___Brackish
___Palustrine	___Semipermanetly Flooded	___Temporarily Flooded/Saturated	___Freshwater
___Lacustrine	___Seasonally Flooded	___Intermittently Flooded	

Environmental Comments:	Unvegetated Surface: (please use the cover scale below)
	___ Bedrock ___ Litter, duff ___ Wood (> 1 cm)
	___ Large rocks (cobbles, boulders > 10 cm)
	___ Small rocks (gravel, 0.2-10 cm)
	___ Sand (0.1-2 mm) ___ Bare soil
	___ Other:_____

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	Cover Scale for Strata & Unvegetated Surface		Height Scale for Strata	
Trees and Shrubs		___Forest				
___Evergreen	___Broad-leaved	___Woodland	01	5%	01	<0.5 m
___Cold-deciduous	___Needle-leaved	___Shrubland	02	10%	02	0.5-1m
___Drought-deciduous	___Mixed broad-leaved/Needle leaved	___Dwarf Shrubland	03	20%	03	1-2 m
___Mixed evergreen - cold-deciduous	___Microphyllous	___Herbaceous	04	30%	04	2-5 m
___Mixed evergreen - drought-deciduous	___Graminoid	___Nonvascular	05	40%	05	5-10 m
	___Forb	___Sparsely Vegetated	06	50%	06	10-15 m
Herbs	___Pteridophyte		07	60%	07	15-20 m
___Annual			08	70%	08	20-35 m
___Perennial			09	80%	09	35 - 50 m
			10	90%	10	>50 m
			11	100%		

Strata	Height	Cover Class	Dominant species (mark any known diagnostic species with a *)	Cover Class
T1 Emergent	_____	_____		
T2 Canopy	_____	_____		
T3 Sub-canopy	_____	_____		
S1 Tall shrub	_____	_____		
S2 Short Shrub	_____	_____		
S3 Dwarf-shrub H Herbaceous	_____	_____		
N Non-vascular	_____	_____		
V Vine/liana	_____	_____		
E Epiphyte	_____	_____		

please see the table on the previous page for height and cover scales for strata

Other Comments

Cover Scale for Species
01 <1%
02 1-5%
03 5-25%
04 25-50%
05 50-75%
06 75-100%

Accuracy assessment Form (1998)
USGS-NPS Vegetation Mapping Program

1. Plot Number _____ 2. Park Code _____ 3. Date _____

4. Observer(s)_____5. Datum _____ 6. Accuracy _____

7. UTM Coordinates: Easting __ __ __, __ __ __ Northing __, __ __ __, __ __ __

8. UTM Zone _____ 9. Offset from Point: Easting _____m Northing _____m

10. Topographic Description _____

11. Elevation _____m 12. Aspect _____

13. Veg Assoc. at Site _____

14. Veg Assoc 2 within 50m of Site _____

15. Veg Assoc 3 within 50m of Site _____

16. Major Species Present (by strata)_____

_____

_____

17. Canopy Closure of Top Layer _____

18. Rationale for Classification_____

_____

_____

_____

19. Comments _____

_____

_____

Appendix D

Accuracy Assessment Contingency Matrix

Using the Accuracy Assessment Contingency Matrix

The accuracy assessment contigency matrix is a separate spreadsheet. The matrix is an array of numbers set out in rows and columns which reveal the number of polygons assigned to a particular vegetation association(s) relative to the actual vegetation type as verified on the ground. The columns represent the vegetation associations and the rows represent the map unit codes. The accuracies of each map unit are described along with both the errors of inclusion (commission errors) and errors of exclusion (omission errors) present in the mapping.

Appendix E

A List of Species found during the Vegetation Mapping Project for Voyageurs National Park

Summarized by Plant Family
Nomenclature follows the PLANTS database

The following list of species includes those found during the Vegetation Mapping Project for Voyageurs National Park. It is not intended to be a comprehensive list of every species that occurs in the Voyageurs National Park Mapping project area. The species are presented alphabetically by family. Lichens and bryophte Families are shaded in gray.

Family	Scientific Name	Common Name
Aceraceae	Acer rubrum L.	red maple
	Acer spicatum Lam.	mountain maple
Acoraceae	Acorus calamus L.	calamus
Alismataceae	Sagittaria cristata Engelm.	crested arrowhead
	Sagittaria latifolia Willd.	broadleaf arrowhead
	Sagittaria rigida Pursh	sessilefruit arrowhead
Amblystegiaceae	Calliergon (Sull.) Kindb.	calliergon moss
	Calliergon cordifolium (Hedw.) Kindb.	calliergon moss
	Calliergon giganteum (Schimp.) Kindb.	giant calliergon moss
	Drepanocladus (C. Mll.) G. Roth	drepanocladus moss
	Drepanocladus aduncus (Hedw.) Warnst.	drepanocladus moss
	Warnstorfia exannulata (Schimp. in B.S.G.) Loeske	warnstorfia moss
Anacardiaceae	Rhus glabra L.	smooth sumac
	Rhus hirta (L.) Sudworth	staghorn sumac
	Toxicodendron radicans ssp. radicans (L.) Kuntze	eastern poison ivy
Aneuraceae	Riccardia multifida	
Apiaceae	Cicuta bulbifera L.	bulblet bearing water hemlock
	Cicuta L.	water hemlock
	Osmorhiza claytonii (Michx.) C.B. Clarke	Clayton's sweetroot
	Osmorhiza longistylis (Torr.) DC.	longstyle sweetroot
	Sanicula marilandica L.	Maryland sanicle
	Sium suave Walt.	hemlock waterparsnip
Apocynaceae	Apocynum androsaemifolium L.	spreading dogbane
Araceae	Arisaema triphyllum (L.) Schott	Jack in the pulpit
	Calla palustris L.	water arum
Araliaceae	Aralia hispida Vent.	bristly sarsaparilla
	Aralia nudicaulis L.	wild sarsaparilla
	Aralia racemosa L.	American spikenard
Aristolochiaceae	Asarum canadense L.	Canadian wildginger
Asteraceae	Achillea millefolium L.	common yarrow
	Anaphalis margaritacea (L.) Benth. & Hook. f.	western pearlyeverlasting
	Antennaria neglecta Greene	field pussytoes
Asteraceae	Aster ciliolatus Lindl.	Lindley's aster
	Aster L.	aster
	Aster lateriflorus (L.) Britt.	calico aster
	Aster macrophyllus L.	bigleaf aster
	Aster puniceus L.	purplestem aster
	Cirsium arvense (L.) Scop.	Canadian thistle
	Cirsium muticum Michx.	swamp thistle
	Cirsium P. Mill.	thistle
	Doellingeria umbellata (P. Mill.) Nees	
	Erigeron strigosus Muhl. ex Willd.	prairie fleabane
	Eupatorium maculatum L.	spotted joepyeweed
	Hieracium kalmii L.	Kalm's hawkweed
	Hieracium scabrum Michx.	rough hawkweed
	Hieracium umbellatum L.	narrowleaf hawkweed
	Lactuca biennis (Moench) Fern.	tall blue lettuce
	Lactuca canadensis L.	Canada lettuce
	Lactuca L.	lettuce
	Megalodonta beckii (Torr. ex Spreng.) Greene	aquatic beggartick

Family	Scientific Name	Common Name
	Petasites frigidus var. palmatus (Ait.) Cronq.	Arctic sweet coltsfoot
	Petasites sagittatus (Banks ex Pursh) Gray	arrowleaf sweet coltsfoot
	Solidago canadensis L.	Canada goldenrod
	Solidago gigantea Ait.	giant goldenrod
	Solidago hispida Muhl. ex Willd.	hairy goldenrod
	Solidago L.	goldenrod
	Solidago nemoralis Ait.	Dyersweed goldenrod
	Solidago uliginosa Nutt.	bog goldenrod
	Taraxacum G.H. Weber ex Wiggers	dandelion
Aulacomniaceae	Aulacomnium palustre (Hedw.) Schwaegr.	aulacomnium moss
Balsaminaceae	Impatiens capensis Meerb.	jewelweed
Betulaceae	Alnus incana ssp. rugosa (Du Roi) Clausen	speckled alder
	Alnus viridis ssp. crispa (Ait.) Turrill	American green alder
	Betula papyrifera Marsh.	paper birch
	Betula pumila var. glandulifera Regel	glandulose birch
	Betula X sandbergii Britt.	Sandberg's birch
	Corylus americana Walt.	American hazelnut
	Corylus cornuta Marsh.	beaked hazelnut
	Ostrya virginiana (P. Mill.) K. Koch	eastern hophornbeam
Brassicaceae	Rorippa Scop.	yellowcress
Bryaceae	Brachymenium erectum (Hook.) Marg.	erect brachymenium moss
Cabombaceae	Brasenia schreberi J.F. Gmel.	watershield
Campanulaceae	Campanula aparinoides Pursh	marsh bellflower
	Campanula rotundifolia L.	bluebell bellflower
Caprifoliaceae	Diervilla lonicera P. Mill.	northern bush honeysuckle
	Linnaea borealis ssp. americana (Forbes) Hulten ex Clausen	
	Lonicera canadensis Bartr. ex Marsh.	American fly honeysuckle
	Lonicera dioica L.	limber honeysuckle
	Lonicera hirsuta Eat.	hairy honeysuckle
	Lonicera oblongifolia (Goldie) Hook.	swamp fly honeysuckle
	Lonicera villosa (Michx.) J.A. Schultes	mountain fly honeysuckle
	Sambucus racemosa var. racemosa L.	
	Symphoricarpos albus (L.) Blake	common snowberry
	Viburnum lentago L.	nannyberry
	Viburnum opulus var. americanum Ait.	American cranberry viburnum
	Viburnum rafinesquianum J.A. Schultes	downy arrowwood
Caryophyllaceae	Stellaria longifolia Muhl. ex Willd.	longleaf starwort
Celastraceae	Celastrus scandens L.	American bittersweet
Ceratophyllaceae	Ceratophyllum demersum L.	coon's tail
Cladoniaceae	Cladina (Nyl.) Nyl.	reindeer lichen
	Cladina mitis (Sandst.) Hustich	reindeer lichen
	Cladina rangiferina (L.) Nyl.	greygreen reindeer lichen
	Cladina stellaris (Opiz) Brodo	star reindeer lichen
	Cladonia P. Browne	cup lichen
Climaciaceae	Climacium dendroides (Hedw.) Web. & Mohr	tree climacium moss
Clusiaceae	Triadenum fraseri (Spach) Gleason	Fraser's marsh St. Johnswort
Conocephalaceae	Conocephalum conicum	
Cornaceae	Cornus alternifolia L. f.	alternateleaf dogwood
	Cornus canadensis L.	bunchberry dogwood
	Cornus racemosa Lam.	gray dogwood

Family	Scientific Name	Common Name
	Cornus rugosa Lam.	roundleaf dogwood
	Cornus sericea ssp. sericea L.	redosier dogwood
Cupressaceae	Juniperus communis var. depressa Pursh	common juniper
	Thuja occidentalis L.	eastern arborvitae
Cyperaceae	Carex aquatilis Wahlenb.	water sedge
	Carex arcta Boott	bear sedge
	Carex bebbii Olney ex Fern.	Bebb's sedge
	Carex brunnescens ssp. sphaerostachya (Tuckerman) Kalela	brownish sedge
	Carex canescens L.	silvery sedge
	Carex chordorrhiza Ehrh. ex L. f.	creeping sedge
	Carex cristatella Britt.	crested sedge
	Carex diandra Schrank	lesser panicled sedge
	Carex disperma Dewey	softleaf sedge
	Carex echinata ssp. echinata Murr.	prickly sedge
	Carex gracillima Schwein.	graceful sedge
	Carex interior Bailey	inland sedge
	Carex intumescens Rudge	greater bladder sedge
	Carex L.	sedge
	Carex lacustris Willd.	hairy sedge
	Carex lasiocarpa var. americana Fern.	American woollyfruit sedge
	Carex leptalea Wahlenb.	bristlystalked sedge
	Carex limosa L.	mud sedge
	Carex livida var. radicaulis Paine	livid sedge
	Carex magellanica ssp. magellanica Lam.	little sedge
	Carex oligosperma Michx.	fewseed sedge
	Carex pauciflora Lightf.	star sedge
	Carex peckii Howe	Peck's sedge
	Carex pensylvanica Lam.	Pennsylvania sedge
	Carex projecta Mackenzie	necklace sedge
	Carex retrorsa Schwein.	knotsheath sedge
	Carex rostrata var. utriculata (Boott) Bailey	= Carex utriculata
	Carex scoparia Schkuhr ex Willd.	broom sedge
	Carex stipata Muhl. ex Willd.	owlfruit sedge
	Carex stricta Lam.	uptight sedge
	Carex tenuiflora Wahlenb.	sparseflower sedge
	Carex trisperma Dewey	threeseeded sedge
	Carex vesicaria L.	blister sedge
	Cladium P. Br.	sawgrass
	Dulichium arundinaceum (L.) Britt.	threeway sedge
	Eriophorum angustifolium Honckeny	tall cottongrass
	Eriophorum chamissonis C.A. Mey.	Chamisso's cottongrass
	Eriophorum gracile W.D.J. Koch	slender cottongrass
	Eriophorum L.	cottongrass
	Eriophorum tenellum Nutt.	fewnerved cottongrass
	Eriophorum vaginatum var. spissum (Fern.) Boivin	tussock cottongrass
	Eriophorum virginicum L.	tawny cottongrass
	Eriophorum viridicarinatum (Engelm.) Fern.	thinleaf cottonsedge
	Scirpus acutus Muhl. ex Bigelow	= Schoenoplectus acutus var. acutus
	Scirpus cyperinus (L.) Kunth	woolgrass
	Scirpus validus var. creber Fern.	= Schoenoplectus tabernaemontani
Dennstaedtiaceae	Pteridium aquilinum var. latiusculum (Desv.) Underwood ex Heller	western brackenfern
Dicranaceae	Dicranum flagellare Hedw.	dicranum moss
	Dicranum Hedw.	dicranum moss
	Dicranum montanum Hedw.	
	Dicranum ontariense Peters.	Ontario dicranum moss
	Dicranum polysetum Sw.	
	Dicranum scoparium Hedw.	

Family	Scientific Name	Common Name
Droseraceae	Drosera rotundifolia L.	roundleaf sundew
Dryopteridaceae	Athyrium filix-femina ssp. angustum (Willd.) Clausen	subarctic ladyfern
	Dryopteris Adans.	woodfern
	Dryopteris carthusiana (Vill.) H.P. Fuchs	spinulose woodfern
	Dryopteris cristata (L.) Gray	crested woodfern
	Gymnocarpium dryopteris (L.) Newman	western oakfern
	Onoclea sensibilis L.	sensitive fern
	Woodsia ilvensis (L.) R. Br.	rusty woodsia
Equisetaceae	Equisetum arvense L.	field horsetail
	Equisetum fluviatile L.	water horsetail
	Equisetum L.	horsetail
	Equisetum pratense Ehrh.	meadow horsetail
	Equisetum scirpoides Michx.	dwarf scouringrush
	Equisetum sylvaticum L.	woodland horsetail
Ericaceae	Andromeda polifolia var. glaucophylla (Link) DC.	bog rosemary
	Arctostaphylos uva-ursi (L.) Spreng.	kinnikinnick
	Chamaedaphne calyculata var. angustifolia (Ait.) Rehd.	leatherleaf
	Gaultheria hispidula (L.) Muhl. ex Bigelow	creeping snowberry
	Gaultheria procumbens L.	eastern teaberry
	Kalmia polifolia Wangenh.	bog laurel
	Ledum groenlandicum Oeder	bog Labradortea
	Vaccinium angustifolium Ait.	lowbush blueberry
	Vaccinium macrocarpon Ait.	cranberry
	Vaccinium myrtilloides Michx.	velvetleaf huckleberry
	Vaccinium oxycoccos L.	small cranberry
	Vaccinium vitis-idaea ssp. minus (Lodd.) Hulten	northern mountain cranberry
Fabaceae	Amphicarpaea bracteata (L.) Fern.	American hogpeanut
	Lathyrus ochroleucus Hook.	cream peavine
	Lathyrus venosus Muhl. ex Willd.	veiny peavine
	Trifolium pratense L.	red clover
	Vicia americana Muhl. ex Willd.	American vetch
Fagaceae	Quercus ellipsoidalis E.J. Hill	northern pin oak
	Quercus L.	oak
	Quercus macrocarpa Michx.	bur oak
	Quercus rubra L.	northern red oak
Fumariaceae	Corydalis DC.	corydalis
	Corydalis sempervirens (L.) Pers.	rock harlequin
Gentianaceae	Halenia deflexa (Sm.) Griseb.	American spurredgentian
Grossulariaceae	Ribes americanum P. Mill.	American black currant
	Ribes aureum var. villosum DC.	golden currant
	Ribes glandulosum Grauer	skunk currant
	Ribes hirtellum Michx.	hairystem gooseberry
	Ribes hudsonianum Richards.	northern black currant
	Ribes L.	currant
	Ribes lacustre (Pers.) Poir.	prickly currant
	Ribes oxyacanthoides L.	Canadian gooseberry
	Ribes triste Pallas	red currant
Haloragaceae	Myriophyllum L.	watermilfoil
	Myriophyllum sibiricum Komarov	shortspike watermilfoil
	Myriophyllum verticillatum L.	whorlleaf watermilfoil
Hedwigiaceae	Hedwigia ciliata (Hedw.) P. Beauv.	ciliate hedwigia moss
Hydrocharitaceae	Elodea canadensis Michx.	Canadian waterweed
	Vallisneria americana Michx.	American eelgrass
Hylocomiaceae	Hylocomium splendens (Hedw.) Schimp. in B.S.G.	splendid feather moss
	Pleurozium Mitt.	big red stem moss
		Schreber's big red stem moss
Hylocomiaceae	Rhytidiadelphus triquetrus (Hedw.) Warnst.	rough goose neck moss

Family	Scientific Name	Common Name
Hypnaceae	Hypnum lindbergii Mitt.	Lindberg's hypnum moss knights plume moss
Iridaceae	Iris versicolor L.	harlequin blueflag
Juncaceae	Luzula acuminata Raf.	hairy woodrush
Lamiaceae	Agastache foeniculum (Pursh) Kuntze	blue giant hyssop
	Clinopodium vulgare L.	wild basil
	Lycopus americanus Muhl. ex W. Bart.	American waterhorehound
	Lycopus L.	waterhorehound
	Lycopus uniflorus Michx.	northern bugleweed
	Mentha canadensis L.	Canadian mint
	Mentha spicata L.	spearmint
	Prunella vulgaris L.	common selfheal
	Scutellaria galericulata L.	marsh skullcap
	Scutellaria L.	skullcap
	Scutellaria lateriflora L.	blue skullcap
Lemnaceae	Lemna minor L.	common duckweed
	Lemna trisulca L.	star duckweed
	Spirodela polyrrhiza (L.) Schleid.	common duckweed
Lentibulariaceae	Utricularia intermedia Hayne	flatleaf bladderwort
	Utricularia L.	bladderwort
	Utricularia macrorhiza Le Conte	common bladderwort
Liliaceae	Clintonia borealis (Ait.) Raf.	yellow bluebeadlily
	Maianthemum canadense Desf.	Canada beadruby
	Maianthemum trifolium (L.) Sloboda	threeleaf false Solomon's seal
	Polygonatum biflorum var. commutatum (J.A. & J.H. Schultes) Morong	king Solomon's seal
	Polygonatum pubescens (Willd.) Pursh	hairy Solomon's seal
	Streptopus lanceolatus var. longipes (Fern.) Reveal	
	Trillium cernuum L.	whippoorwill flower
	Uvularia grandiflora Sm.	largeflower bellwort
Lycopodiaceae	Huperzia lucidula (Michx.) Trevisan	shining clubmoss
	Lycopodium annotinum L.	stiff clubmoss
	Lycopodium clavatum L.	running clubmoss
	Lycopodium complanatum L.	groundcedar
	Lycopodium dendroideum Michx.	tree groundpine
	Lycopodium hickeyi W.H. Wagner, Beitel & Moran	Pennsylvania clubmoss
Lythraceae	Lythrum salicaria L.	purple loosestrife
Menyanthaceae	Menyanthes trifoliata L.	common buckbean
Mniaceae		mnium calcareous moss
	Plagiomnium T. Kop.	
	Rhizomnium magnifolium (Horik.) T. Kop.	grandleaf rhizomnium moss
	Rhizomnium pseudopunctatum (Bruch & Schimp.) T. Kop.	rhizomnium moss
Monotropaceae	Monotropa uniflora L.	Indianpipe
Myricaceae	Comptonia peregrina (L.) Coult.	sweet fern
	Myrica gale L.	sweetgale
Najadaceae	Najas flexilis (Willd.) Rostk. & Schmidt	nodding waternymph
Nymphaeaceae	Nuphar lutea ssp. variegata (Dur.) E.O. Beal	varigated yellow pondlily
	Nymphaea odorata Ait.	American white waterlily
Oleaceae	Fraxinus nigra Marsh.	black ash
	Fraxinus pennsylvanica Marsh.	green ash
Onagraceae	Circaea alpina L.	small enchanter's nightshade
	Circaea lutetiana ssp. canadensis (L.) Aschers. & Magnus	broadleaf enchanter's nightshade
	Epilobium coloratum Biehler	purpleleaf willowherb

Family	Scientific Name	Common Name
	Epilobium L.	willowweed
	Epilobium leptocarpum Hausskn.	slenderfruit willowherb
	Epilobium palustre L.	marsh willowherb
Ophioglossaceae	Botrychium Sw.	grapefern
	Botrychium virginianum (L.) Sw.	rattlesnake fern
Orchidaceae	Arethusa bulbosa L.	dragon's mouth
	Corallorrhiza maculata (Raf.) Raf.	summer coralroot
	Corallorrhiza striata Lindl.	hooded coralroot
	Cypripedium acaule Ait.	pink lady's slipper
Orchidaceae	Cypripedium reginae Walt.	showy lady's slipper
	Goodyera repens (L.) R. Br. ex Ait. f.	lesser rattlesnake plantain
	Goodyera tesselata Lodd.	checkered rattlesnake plantain
	Malaxis brachypoda (Gray) Fern.	white addersmouth orchid
	Platanthera hyperborea (L.) Lindl.	northern green orchid
	Platanthera orbiculata (Pursh) Lindl.	large roundleaved orchid
Osmundaceae	Osmunda cinnamomea L.	cinnamon fern
	Osmunda claytoniana L.	interrupted fern
Pinaceae	Abies balsamea (L.) P. Mill.	balsam fir
	Larix laricina (Du Roi) K. Koch	tamarack
	Picea glauca (Moench) Voss	white spruce
	Picea mariana (P. Mill.) B.S.P.	black spruce
	Pinus banksiana Lamb.	jack pine
	Pinus resinosa Soland.	red pine
	Pinus strobus L.	eastern white pine
Poaceae	Agropyron Gaertn.	wheatgrass
	Agrostis L.	bentgrass
	Agrostis scabra Willd.	rough bentgrass
	Agrostis stolonifera L.	creeping bentgrass
	Bromus ciliatus L.	fringed brome
	Calamagrostis canadensis (Michx.) Beauv.	bluejoint
	Cinna latifolia (Trev. ex Goepp.) Griseb.	drooping woodreed
	Danthonia spicata (L.) Beauv. ex Roemer & J.A. Schultes	poverty danthonia
	Dichanthelium scabriusculum (Ell.) Gould & C.A. Clark	woolly rosette grass
	Dichanthelium xanthophysum (Gray) Freckmann	slender rosette grass
	Elymus trachycaulus ssp. trachycaulus (Link) Gould ex Shinners	slender wheatgrass
	Elymus virginicus L.	Virginia wildrye
	Glyceria canadensis (Michx.) Trin.	rattlesnake mannagrass
	Glyceria grandis S. Wats.	American mannagrass
	Glyceria striata (Lam.) A.S. Hitchc.	fowl mannagrass
	Oryzopsis asperifolia Michx.	roughleaf ricegrass
	Oryzopsis pungens (Torr. ex Spreng.) A.S. Hitchc.	mountain ricegrass
	Panicum capillare L.	witchgrass
	Panicum L.	panicum
	Phleum pratense L.	timothy
	Phragmites australis (Cav.) Trin. ex Steud.	common reed
	Poa alsodes Gray	grove bluegrass
	Poa L.	bluegrass
	Schizachne purpurascens (Torr.) Swallen	false melic
	Torreyochloa pallida (Torr.) Church	pale false mannagrass
	Zizania palustris L.	northern wildrice
Polygonaceae	Polygonum amphibium var. stipulaceum Coleman	water smartweed
	Polygonum cilinode Michx.	fringed black bindweed
	Polygonum douglasii Greene	Douglas' knotweed
	Polygonum hydropiper L.	marshpepper knotweed
	Polygonum L.	knotweed
	Polygonum lapathifolium L.	curlytop knotweed
	Polygonum punctatum Ell.	dotted smartweed
	Polygonum sagittatum L.	arrowleaf tearthumb
	Polygonum virginianum L.	jumpseed

Family	Scientific Name	Common Name
	Rumex altissimus Wood	pale dock
	Rumex crispus L.	curly dock
	Rumex orbiculatus Gray	greater water dock
Polypodiaceae	Polypodium virginianum L.	rock polypody
Polytrichaceae	Polytrichum commune Hedw.	polytrichum moss
	Polytrichum Hedw.	polytrichum moss
	Polytrichum juniperinum Hedw.	juniper polytrichum moss
	Polytrichum piliferum Hedw.	polytrichum moss
	Polytrichum strictum Brid.	polytrichum moss
Potamogetonaceae	Potamogeton friesii Rupr.	Fries' pondweed
	Potamogeton gramineus L.	variableleaf pondweed
	Potamogeton L.	pondweed
	Potamogeton natans L.	floating pondweed
	Potamogeton richardsonii (Benn.) Rydb.	Richardson's pondweed
	Potamogeton spirillus Tuckerman	spiral pondweed
	Potamogeton zosteriformis Fern.	flatstem pondweed
Primulaceae	Lysimachia L.	loosestrife
	Lysimachia terrestris (L.) B.S.P.	earth loosestrife
	Lysimachia thyrsiflora L.	tufted loosestrife
	Trientalis borealis Raf.	American starflower
Pyrolaceae	Chimaphila umbellata ssp. cisatlantica (Blake) Hulten	pipsissewa
	Moneses uniflora (L.) Gray	single delight
	Orthilia secunda (L.) House	sidebells wintergreen
	Pyrola americana Sweet	American wintergreen
	Pyrola asarifolia Michx.	liverleaf wintergreen
Pyrolaceae	Pyrola chlorantha Sw.	greenflowered wintergreen
	Pyrola elliptica Nutt.	waxflower shinleaf
Pyrolaceae	Pyrola L.	pyrola
Ranunculaceae	Actaea L.	baneberry
	Actaea rubra (Ait.) Willd.	red baneberry
	Anemone quinquefolia var. bifolia Farw.	twoleaf anemone
	Aquilegia canadensis L.	red columbine
	Caltha palustris L.	yellow marshmarigold
	Coptis trifolia ssp. groenlandica (Oeder) Hulten	threeleaf goldthread
	Hepatica nobilis var. obtusa (Pursh) Steyermark	roundlobed hepatica
	Thalictrum dasycarpum Fisch. & Ave-Lall.	purple meadowrue
Rhamnaceae	Rhamnus alnifolia L'Her.	alderleaf buckthorn
Rosaceae	Agrimonia L.	agrimony
	Amelanchier Medik.	serviceberry
	Amelanchier sanguinea (Pursh) DC.	roundleaf serviceberry
	Aronia melanocarpa (Michx.) Ell.	black chokeberry
	Comarum palustre L.	purple marshlocks
Rosaceae	Crataegus chrysocarpa Ashe	fireberry hawthorn
	Crataegus L.	hawthorn
	Fragaria L.	strawberry
	Fragaria vesca ssp. americana (Porter) Staudt	woodland strawberry
	Fragaria virginiana Duchesne	Virginia strawberry
	Geum aleppicum Jacq.	yellow avens
	Geum macrophyllum var. perincisum (Rydb.) Raup	largeleaf avens
	Geum rivale L.	purple avens
	Potentilla norvegica L.	Norwegian cinquefoil
	Prunus pensylvanica L. f.	pin cherry
	Prunus pumila L.	sand cherry
	Prunus virginiana L.	common chokecherry
	Rosa acicularis ssp. sayi (Schwein.) W.H. Lewis	prickly rose
	Rubus arcticus ssp. acaulis (Michx.) Focke	dwarf raspberry
	Rubus idaeus ssp. strigosus (Michx.) Focke	grayleaf red raspberry
	Rubus occidentalis L.	black raspberry

Family	Scientific Name	Common Name
	Rubus pubescens Raf.	dwarf red blackberry
	Sorbus americana Marsh.	American mountainash
	Sorbus decora (Sarg.) Schneid.	northern mountainash
	Sorbus L.	mountainash
	Spiraea alba Du Roi	white meadowsweet
Rubiaceae	Galium asprellum Michx.	rough bedstraw
	Galium boreale L.	northern bedstraw
	Galium L.	bedstraw
	Galium labradoricum (Wieg.) Wieg.	northern bog bedstraw
	Galium obtusum Bigelow	bluntleaf bedstraw
	Galium trifidum L.	threepetal bedstraw
	Galium triflorum Michx.	fragrant bedstraw
Salicaceae	Populus balsamifera L.	balsam poplar
	Populus grandidentata Michx.	bigtooth aspen
	Populus tremuloides Michx.	quaking aspen
	Salix bebbiana Sarg.	Bebb willow
	Salix candida Fluegge ex Willd.	sageleaf willow
	Salix discolor Muhl.	pussy willow
	Salix eriocephala Michx.	Missouri River willow
	Salix humilis Marsh.	prairie willow
	Salix L.	willow
	Salix pedicellaris var. pedicellaris	bog willow
	Salix petiolaris Sm.	meadow willow
	Salix planifolia Pursh	diamondleaf willow
	Salix pyrifolia Anderss.	balsam willow
	Salix serissima (Bailey) Fern.	autumn willow
Santalaceae	Comandra umbellata (L.) Nutt.	bastard toadflax
Sarraceniaceae	Sarracenia purpurea L.	purple pitcherplant
Saxifragaceae	Heuchera richardsonii R. Br.	Richardson's alumroot
	Mitella nuda L.	naked miterwort
	Saxifraga pensylvanica L.	eastern swamp saxifrage
Scheuchzeriaceae	Scheuchzeria palustris ssp. americana (Fern.) Hulten	American scheuchzeria
Scrophulariaceae	Melampyrum lineare Desr.	narrowleaf cowwheat
Selaginellaceae	Selaginella rupestris (L.) Spring	northern selaginella
Sparganiaceae	Sparganium eurycarpum Engelm. ex Gray	broadfruit burreed
	Sparganium fluctuans (Morong) B.L. Robins.	floating burreed
Sphagnaceae	Sphagnum capillifolium (Ehrh.) Hedw.	sphagnum
	Sphagnum centrale C. Jens. in Arnell & C. Jens.	sphagnum
	Sphagnum contortum Schultz	contorted sphagnum
	Sphagnum fimbriatum Wils. in Wils. & Hook. f. in Hook. f.	sphagnum
	Sphagnum fuscum (Schimp.) Klinggr.	sphagnum
	Sphagnum girgensohnii Russ.	Girgensohn's sphagnum
	Sphagnum L.	sphagnum
	Sphagnum magellanicum Brid.	Magellan's sphagnum
	Sphagnum nitidum Warnst.	sphagnum
	Sphagnum papillosum Lindb.	papillose sphagnum
	Sphagnum recurvum P. Beauv.	recurved sphagnum
	Sphagnum russowii Warnst.	Russow's sphagnum
	Sphagnum squarrosum Crome	sphagnum
	Sphagnum subsecundum Nees in Sturm	sphagnum
	Sphagnum tenerum Sull. & Lesq. in Sull. in Gray	sphagnum
	Sphagnum teres (Schimp.) Angstr. in Hartm.	sphagnum
Sphagnaceae	Sphagnum warnstorfii Russ.	Warnstorf's sphagnum
	Sphagnum wulfianum Girg.	Wulf's sphagnum
Thelypteridaceae	Phegopteris connectilis (Michx.) Watt	long beechfern
	Thelypteris palustris Schott	eastern marsh fern

Family	Scientific Name	Common Name
	Thelypteris Schmidel	maiden fern
Thuidiaceae	Thuidium delicatulum (Hedw.) Schimp. in B.S.G.	delicate thuidium moss
	Thuidium recognitum (Hedw.) Lindb.	thuidium moss
	Thuidium Schimp. in B.S.G.	thuidium moss
Tiliaceae	Tilia americana L.	American basswood
Typhaceae	Typha angustifolia L.	narrowleaf cattail
	Typha L.	cattail
	Typha latifolia L.	broadleaf cattail
	Typha X glauca Godr. (pro sp.)	white cattail
Ulmaceae	Ulmus americana L.	American elm
Urticaceae	Urtica dioica ssp. gracilis (Ait.) Seland.	California nettle
Violaceae	Viola adunca Sm.	hookedspur violet
	Viola L.	violet
	Viola novae-angliae House	New England blue violet
Violaceae	Viola pubescens Ait.	downy yellow violet
	Viola renifolia Gray	white violet
Vitaceae	Parthenocissus quinquefolia var. quinquefolia (L.) Planch.	Virginia creeper