National Park Service
U.S. Department of the Interior

Northeast Region
Philadelphia, Pennsylvania

Vegetation Classification and Mapping of Hopewell Furnace National Historic Site

Technical Report NPS/NER/NRTR--2005/012

Dry Oak–Heath Forest at Hopewell Furnace National Historic Site
Photograph by: Greg Podniesinski, Pennsylvania Science Office of The Nature Conservancy

Vegetation Classification and Mapping of Hopewell Furnace National Historic Site

Technical Report NPS/NER/NRTR--2005/012

Greg Podniesinski, Stephanie Perles, Lesley Sneddon[1], Bill Millinor[2]

Pennsylvania Science Office of The Nature Conservancy
208 Airport Drive
Middletown, PA 17057

[1]NatureServe
11 Avenue de Lafayette, 5th Floor
Boston MA 02111

[2]North Carolina State University
Center for Earth Observation
5112 Jordan Hall, Box 7106
Raleigh, NC 27695

March 2005 (revised October 2005)

U.S. Department of the Interior
National Park Service
Northeast Region
Philadelphia, Pennsylvania

The Northeast Region of the National Park Service (NPS) comprises national parks and related areas in 13 New England and Mid-Atlantic states. The diversity of parks and their resources are reflected in their designations as national parks, seashores, historic sites, recreation areas, military parks, memorials, and rivers and trails. Biological, physical, and social science research results, natural resource inventory and monitoring data, scientific literature reviews, bibliographies, and proceedings of technical workshops and conferences related to these park units are disseminated through the NPS/NER Technical Report (NRTR) and Natural Resources Report (NRR) series. The reports are a continuation of series with previous acronyms of NPS/PHSO, NPS/MAR, NPS/BSO-RNR, and NPS/NERBOST. Individual parks may also disseminate information through their own report series.

Natural Resources Reports are the designated medium for information on technologies and resource management methods; "how to" resource management papers; proceedings of resource management workshops or conferences; and natural resource program descriptions and resource action plans.

Technical Reports are the designated medium for initially disseminating data and results of biological, physical, and social science research that addresses natural resource management issues; natural resource inventories and monitoring activities; scientific literature reviews; bibliographies; and peer-reviewed proceedings of technical workshops, conferences, or symposia.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Park Service.

This report was accomplished under Cooperative Agreement 4560A0019, Amendment No. 2 and Cooperative Agreement 4560040025, Task Agreement No. 1 with assistance from the NPS. The statements, findings, conclusions, recommendations, and data in this report are solely those of the author(s), and do not necessarily reflect the views of the U.S. Department of the Interior, National Park Service.

Reports in these series are produced in limited quantities and, as long as the supply lasts, may be obtained by sending a request to the address on the back cover. When original quantities are exhausted, copies may be requested from the NPS Technical Information Center (TIC), Denver Service Center, PO Box 25287, Denver, CO 80225-0287. A copy charge may be involved. To order from TIC, refer to document D-96.

This report may also be available as a downloadable portable document format file from the Internet at http://www.nps.gov/nero/science/.

Please cite this publication as:

Podniesinski, G. S., S. J. Perles, L. A. Sneddon, B. Millinor. March 2005 (revised October 2005). Vegetation Classification and Mapping of Hopewell Furnace National Historic Site. Technical Report NPS/NER/NRTR--2005/012. National Park Service. Philadelphia, PA.

NPS D-96 March 2005 (revised October 2005)

Table of Contents

Page

Figures vi

Tables vii

Appendixes vii

Executive Summary ix

Acknowledgments x

Introduction 1

Purpose 1

General Background 1

Vegetation Classification System 1

Project Area 3

General Description 3

Geology 3

Land Use History 6

Methods 7

Overview of Vegetation Mapping Methodology 7

Acquisition of Aerial Photography of Park 7

Development of Aerial Photo Mosaic and Positional Accuracy Assessment 7

Air Photo Interpretation 9

Field Data Collection and Classification 9

Planning 9

Field Survey 9

Vegetation Sampling 10

Table of Contents (continued)

Page

Data Analysis 11

Vegetation Key 11

Thematic Accuracy Assessment Field Methods 12

Results 14

Vegetation Classification and Characterization 14

Local Alliance Descriptions 14

Tulip Poplar Forest 17

Dry Oak–Heath Forest 17

Dry Oak–Mixed Hardwood Forest 18

Modified Successional Forest 18

Red Maple–Mixed Hardwood Palustrine Forest 18

Successional Scrub–Shrub (Powerline Right-of-Way Corridor) 19

Birch Rocky Slope Woodland 19

Eastern Red Cedar Woodland 19

Modified Successional Woodland 20

Highbush Blueberry–Meadowsweet Wetland 20

Buttonbush Wetland 20

Skunk Cabbage–Golden Saxifrage Forested Seep 20

Grassland 21

Vegetation Map Production 21

Accuracy Assessment 28

Positional Accuracy Assessment 28

Table of Contents (continued)

Page

Thematic Accuracy Assessment 28

Final Alliance-Level Map 28

Project Deliverables 32

Discussion 34

Vegetation Classification and Characterization 34

Map Production 36

References Cited 37

Figures

Page

Figure 1. Location of Hopewell Furnace National Historic Site, Pennsylvania. 4

Figure 2. Bedrock geology of Hopewell Furnace National Historic Site. 5

Figure 3. Location of aerial photography flight lines and centerpoints of individual photographs used to develop ortho-rectified digital photograph mosaic for Hopewell Furnace National Historic Site. 8

Figure 4. Location of vegetation classification sampling plots at Hopewell Furnace National Historic Site. 15

Figure 5. Graph of Non-metric Multi-dimensional Scaling (NMS) ordination of vegetation classification plot data. 16

Figure 6. Thematic accuracy assessment sampling locations at Hopewell Furnace National Historic Site. 30

Figure 7. Final alliance-level vegetation map for Hopewell Furnace National Historic Site. 31

Tables

Page

Table 1. A summary of the number and total area of anthropogenic and natural polygons for the Hopewell Furnace National Historic Site formation-level map. 22

Table 2. A summary of the number of polygons and total area by alliance for the final alliance-level vegetation map for Hopewell Furnace National Historic Site. 26

Table 3. Results of thematic accuracy assessment sampling at Hopewell Furnace National Historic Site. 29

Table 4. Summary of products resulting from Hopewell Furnace National Historic Site vegetation mapping project. 33

Appendixes

Page

Appendix A. Procedures used to develop a digital orthophoto mosaic for Hopewell Furnace National Historic Site. 39

Appendix B. Vegetation classification plot sampling and accuracy assessment field forms. 45

Appendix C. Key to vegetation types at Hopewell Furnace National Historic Site. 50

Appendix D. Detailed NVCS vegetation classification alliance descriptions. 57

Appendix E. List of vascular plants identified in vegetation classification and accuracy assessment plots (nomenclature follows Kartez 1994). 68

Appendix F. Photos of vegetation classification sampling plots with index to photos. 75

Executive Summary

The vegetation of Hopewell Furnace National Historic Site was mapped during 2002 and 2003 as part of the U.S. Geological Survey (USGS) / National Park Service (NPS) Vegetation Mapping Program. The goal of the mapping effort was to produce an up-to-date digital geospatial vegetation database for the park. New aerial photography was obtained for the park in spring 2002 by Kucera International and converted to a digital orthophoto mosaic image by the North Carolina State University Center for Earth Observation in early summer 2002. The Pennsylvania Science Office of The Nature Conservancy (PSO/TNC) interpreted the photography and developed a digital formation-level vegetation map. PSO/TNC sampled 35 vegetation classification plots during the summer of 2003. Data analysis identified 12 natural or semi-natural vegetation types. Vegetation analysis information was used to reclassify formation-level polygons to develop an alliance-level vegetation map. Accuracy assessment of the alliance-level map constituted a complete census of natural and semi-natural vegetation polygons. Overall accuracy, as measured by the Kappa Index, was 88.77% ± 8.16% (90% C.I.). The majority of mapping errors were associated with Tulip Poplar Forest and Modified Successional Forest. NatureServe provided crosswalk information between park vegetation types and National Vegetation Classification System (NVCS) alliance types as well as alliance descriptions. The resulting vegetation mapping product represents current vegetation types within the park and is consistent with the standards of the USGS/NPS Vegetation Mapping Program.

Natural vegetation types that are relatively undisturbed were easily crosswalked to the corresponding NVCS alliance. Disturbed vegetation types, especially the modified successional forest, had no NVCS equivalent and were noted as park-specific types. The Eastern Red Cedar Woodland was crosswalked to the Eastern Red Cedar Forest Alliance as no NVCS woodland alliance currently exists for a red cedar woodland. Anthropogenic vegetation types were not crosswalked to the NVCS, with the exception of managed grasslands, which were crosswalked to the Orchard Grass–Sheep-sorrel Herbaceous Alliance.

The most common vegetation types were the Dry Oak–Heath and Dry Oak–Mixed Hardwood Forests which, combined, covered approximately 203 ha of the park (approximately 56% of park). Of the upland forests, these two forest types tended to be the most intact with respect to low invasive and exotic species abundance. The least common natural vegetation types included the Birch Rocky Slope Woodland (limited to a single [0.75 ha] patch on a bouldery slope in the southwest corner of the park). Other uncommon vegetation types included shrub wetlands (Buttonbush Wetland and Highbush Blueberry–Meadowsweet Wetland). The single occurrence of the Buttonbush Wetland is within the active pasture and is very degraded. None of the vegetation types described at Hopewell Furnace NHS are rare in Pennsylvania.

Natural vegetation quality within the park ranged from fair (dry oak forests) to poor (Buttonbush Wetland, some Red Maple Palustrine Forest), reflecting the relative ease with which invasive species can colonize wet and mesic soils. In addition, all portions of the park, especially forests of all types, appear to have heavy deer browse damage visible on tree regeneration and shrubs.

Acknowledgments

We would like to thank NPS staff who reviewed and provided comments that greatly improved this report, including Jeff Shreiner, Meghan Carfioli and Steven Ambrose. We would also like to thank John Karish and Beth Johnson, without whose support and enthusiasm this project could not have been accomplished. John Kunsman provided invaluable expertise in field inventory and plant identification. Susan Klugman provided her GIS and data management expertise and assistance in the development of digital mapping and data products.

Introduction

Purpose

The purpose of the vegetation mapping effort at Hopewell Furnace National Historic Site is two-fold. First, a vegetation classification is developed to identify the types of vegetation within the park. The collection of quantitative vegetation data allows the development of descriptions for each type and the development of a vegetation key. The vegetation descriptions and key allow vegetation mappers, as well as park resource managers, to identify various vegetation types in the field. The second purpose of the vegetation mapping effort is the production of a digital vegetation map. Using new aerial photography and information gathered for vegetation classification, photointerpreters develop a digital map showing the distribution and extent of each vegetation type within the park. The accuracy of the vegetation mapping is assessed and the map corrected as appropriate. The resulting digital map provides park managers with a spatial data layer that can be used in assessing park resources as well as planning and management needs.

General Background

A detailed description and map of the vegetation of Hopewell Furnace National Historic Site was developed using the National Vegetation Classification System developed by The Nature Conservancy and NatureServe (formerly the Association for Biological Information) in conjunction with the Federal Geographic Data Committee and the Ecological Society of America Vegetation Subcommittee. The final product, a digital map with descriptions of the component vegetation types and all relating metadata files, provides vegetation information in a format that can be useful for the various operations of the National Park Service, including natural resource managers, planners, acquisition specialists, and biologists. Similar products are currently being applied at Assateague Island National Seashore (The Nature Conservancy 1995) and elsewhere across the country. The product was also developed to provide the natural resource managers with baseline information about the site. Current information exists about the flora of the park, including stand data on forest plots (Bowersox and Larrick 1999) and locations of rare species (Pennsylvania Natural Diversity Inventory database), but a more comprehensive and up-to-date map and description of the park's vegetation were needed. This report also provides a means of comparing and evaluating the park's resources in the context of a regional and national vegetation classification. Information on community composition and rarity can inform decisions on the management of particular areas and natural communities within the park. Such information is critical to ensure the persistence of the native plant and animal species in the park in light of human use, invasion of nonnative plant species, deer browse impacts, and other disturbances to the habitats.

Vegetation Classification System

The Nature Conservancy, in partnership with the network of Natural Heritage Programs, has developed a classification of vegetation of the United States (Grossman et al. 1998). This system has been adopted by the Federal Geographic Data Committee and the Ecological Society of America Vegetation Subcommittee as the national vegetation mapping standard, the National

Vegetation Classification System (NVCS). Although the two systems (Grossman et al. 1988 and the NVCS) are nearly identical, The Nature Conservancy continues to refine the classification through an active review process with state Natural Heritage Programs and academics. The responsibility of the NVCS, including review and revision, is now under jurisdiction of NatureServe (formerly the Association for Biodiversity Information), with central offices in Arlington, VA. Portions of the classification are now available online at www.natureserve.org (NatureServe 2001).

The classification system is hierarchical with the upper levels defined by vegetation physiognomy. This level is the Formation, and "represents vegetation types that share a definite physiognomy or structure within broadly defined environmental factors, relative landscape positions, or hydrologic regimes" (Grossman et al. 1998). Nested within formations are Alliances. An alliance is a physiognomically uniform group of plant associations sharing one or more dominant or diagnostic species usually found in the uppermost stratum of the vegetation. Alliance names typically include the dominant or diagnostic species. Alliances are generally more wide-ranging geographically than are associations, although many monotypic alliances have been classified.

The basic unit of the classification system, the association, is roughly equivalent in scale to the plant association of European phytosociologists. The association is a unit of vegetation that is more or less homogeneous in composition and structure and occurs on uniform habitat. Although associations are defined by the plants that comprise them, they are, in fact, communities of all the component organisms of that association, including animals, protozoans, bacteria, and fungi. Associations are classified from a national perspective and are assigned global rarity ranks, as well as ranking specifications to be applied to individual occurrences of associations across their range.

Vegetation mapping at Hopewell Furnace National Historic Site was done at the alliance level; however, within the park, all of the alliances are monotypic (one association per alliance). A map of alliances occurring at a site can provide information about the abundance and distribution of each type and the significance of the individual occurrences, as well as providing surrogate information about the location and abundance of individual species characteristic of the alliance within the park.

An example of the NVCS hierarchy for an alliance found in the park is as follows (e.g. for Dry Oak Heath Forest). Note that the mapping for at Hopewell Furnace National Historic Site was done at the alliance level only.

Formation: Seasonally Flooded Cold-deciduous Forest
- Alliance: *Acer rubrum–Fraxinus pennsylvanica* Seasonally Flooded Forest
  - Association: *Acer rubrum – Fraxinus (pennsylvanica, americana) / Lindera benzoin / Symplocarpus foetidus* Forest

Project Area

General Description

Hopewell Furnace National Historic Site is located in Berks and Chester counties in southeastern Pennsylvania (Figure 1) within the French Creek drainage. The park is approximately 360 ha in size and is roughly 78% forested, 14% managed grasslands and cropland, and 8% developed land and infrastructure. The major forest cover in this region is the Mixed Oak Forest (Oplinger and Halma 1988, Monk et al. 1990). This general forest type extends from northern Georgia to southern New England. Little to none of the original forest type remains in Berks and Chester counties. This area was formerly part of Braun's Oak–Chestnut Region (Braun 1950), but with the demise of the American chestnut (*Castanea dentata*) and repeated logging and clearing of forest in the region the composition of the forest has changed. Species that were likely minor components of the region's forest have now become dominant species in many areas (e.g., tulip poplar [*Liriodendron tulipifera]* and red maple [*Acer rubrum*]). In addition, the region's forests have undergone invasion by numerous nonnative herb, shrub, and tree species, further altering forest composition and ecology.

Geology

The park lies at the southern edge of the Newark Basin, an exposed rift basin formed in the Late Jurassic–Early Triassic period (Root and Maclachan 1999). The northern end of the park is a low rolling hill of erosion-resistant quartz conglomerate and sandstone of the Triassic Hammer Creek Formation (Figure 2). The lowlands running through the center of the park consist of the more easily weathered Triassic Stockton Formation (arkosic sandstone, sandstone, siltstone, and mudstone). The Stockton Formation rests unconformably upon much older Cambrian and Precambrian bedrock found in the southern third of the park. Precambrian mafic, felsic, and graphitic gneiss, along with the Cambrian Chickies Formation (quartzite, quartz schist, slate, and conglomerate), form rolling hills across the southern portion of the park. Also, the Chickies Formation gives rise to a steep boulder field formation along the west-central edge of the park.

The underlying geology and resulting geomorphology of the park have greatly influenced the type and distribution of vegetation. The erosion resistant bedrock of the northern and southern thirds of the park has given rise to thin, rocky, well drained, and excessively well drained soils favoring oak-dominated forests and woodlands. The weathering of the softer bedrock in the center of the park has created a valley with deeper, richer soils favoring mesic and wet forest vegetation. Associated with the valley are mid- and low-slope areas of groundwater discharge which favor forested seeps and shrub wetlands. Along French Creek, the nearly-level floodplain is characterized by poorly drained, fine textured alluvial deposits, favoring development of palustrine shrublands and forests.

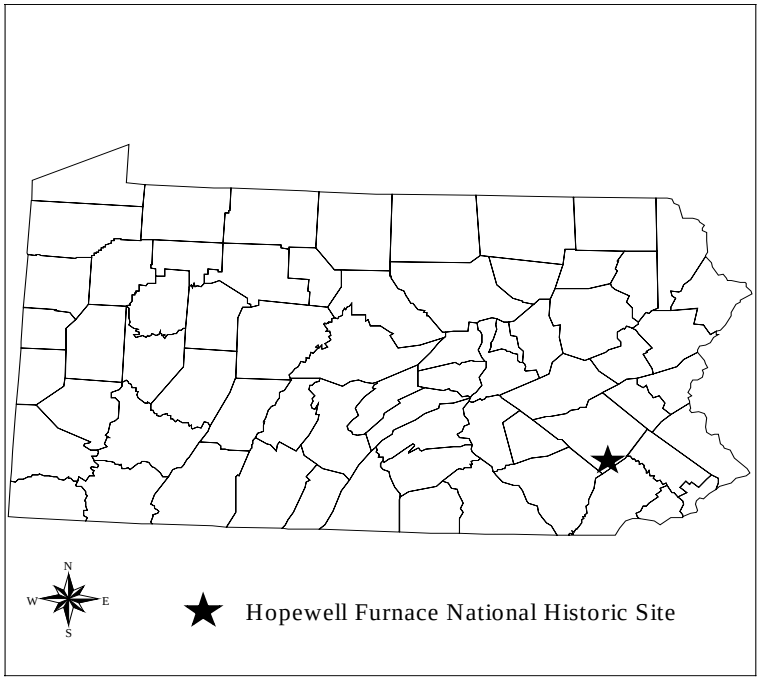
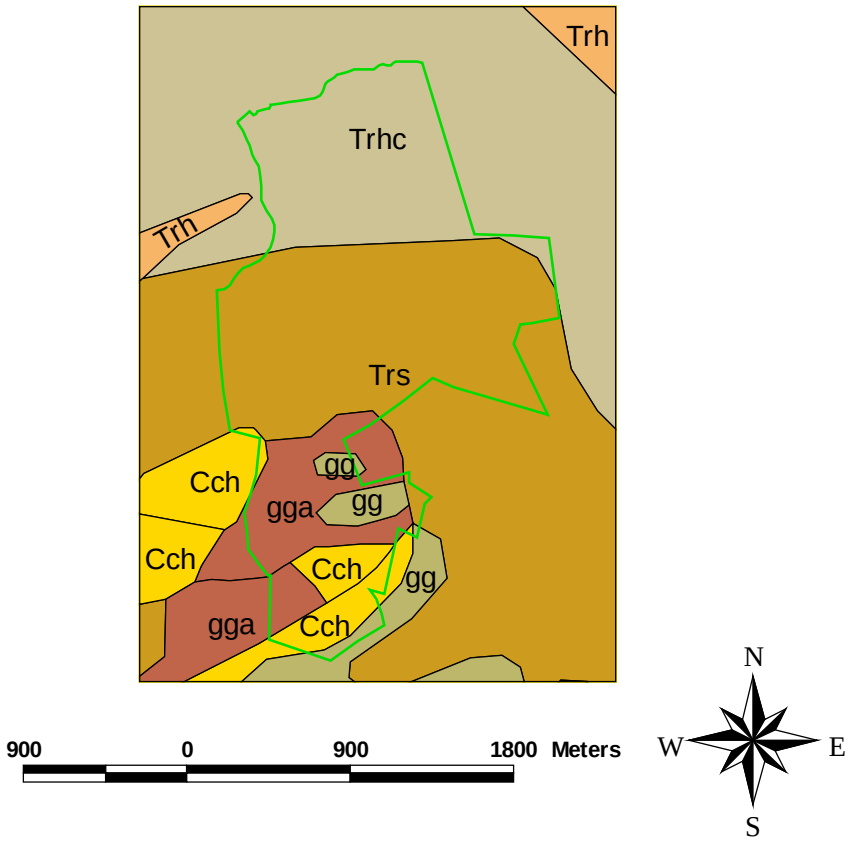


Figure 1. Location of Hopewell Furnace National Historic Site, Pennsylvania.



Geologic formations within Hopewell Furnace NHS

gga = Pre-Cambrian Banded mafic gneiss:mafic gneiss, feldic gneiss
Cch = Cambrian Chickies Formation: quartzite, quartz schist, slate, conglomerate
gg = Pre-Cambrian Graphitic felsic gneiss: graphitic gneiss, felsic gneiss
Trh = Triassic Hammer Creek Formation: sandstone, siltstone, mudstone
Trhc = Hammer Creek conglomerate: Quartz conglomerate, sandstone
Trs = Triassic Stockton Formation: arkosic sandstone, siltstone, sandstone, mudstone

= Hopewell Furnace National Historic Site Boundary

Note: Geologic formation spatial data derived from "Bedrock Geology of Pennsylvania; shape-file format", Pennsylvania Bureau of Topographic and Geographic Survey, Dept. of Conservation and Natural Resources, 2001

Figure 2. Bedrock geology of Hopewell Furnace National Historic Site.

Land Use History

Hopewell Furnace National Historic Site (Hopewell Furnace NHS) was an important iron smelting and casting community in the eighteenth and nineteenth centuries. The reliance on charcoal in the iron-smelting process resulted in the removal of much, if not all, of the forests within the park boundary during this period. In addition, much of the park had been used for cropland or pasture in support of the iron-making community at Hopewell Furnace. Following the decline of the iron smelting and casting industry at Hopewell in the late nineteenth century, some of the farmland was abandoned, resulting in the redevelopment of forest within many portions of the park. The current landscape of the park is a mosaic of early- to mid-successional upland forests, developed land, open and forested wetlands, and agricultural land (pasture, hayfields, and cropland).

Methods

Overview of Vegetation Mapping Methodology

The outline below explains the sequence of steps used to develop a vegetation classification and map for the Hopewell Furnace National Historic Site. The methodology is based on procedures developed by Environmental Systems Research Institute (ESRI) and The Nature Conservancy (TNC) for the United States Geological Survey and National Park Service Vegetation Mapping Program.

Acquisition of Aerial Photography of Park

Recent aerial photography (usually less than five years old) that provides sufficient resolution and detail for classifying vegetation to the alliance level is required for mapping current park vegetation. At Hopewell Furnace NHS no such imagery was available, so new aerial photography was required. Aerial photographs were obtained by Kucera International, flown in April 2002, at a scale of 1:6000. Figure 3 shows the location of aerial photography flight lines and center points of individual photographs.

Development of Aerial Photo Mosaic and Positional Accuracy Assessment

The delineation of mapping polygons using onscreen digitizing is greatly facilitated by the availability of a single seamless digital image of the target area (i.e. extent of park). This is accomplished by scanning hard copies of aerial photography to create digital images and then geo-referencing and ortho-correcting each scanned image. These individual images are then digitally joined to create a single seamless digital aerial photo mosaic. The positional accuracy of the photo mosaic is then assessed by obtaining actual field coordinates for distinct landmarks in the digital image using global positioning system equipment. Field and digital image coordinates are then compared to assess the spatial accuracy of the digital image.

North Carolina State University (NCSU) processed the aerial photography, scanning each photograph and assembling them into a digital ortho-rectified photo mosaic as described above. Horizontal accuracy was assessed on the basis of 12 field survey points distributed throughout the image. The actual field coordinates for these points were recorded with a Trimble ProXRS GPS unit with real-time differential correction with a minimum of 180 fixes per point. The field coordinates were then post-processed using differential correction. The field coordinates were then compared to the image mosaic coordinates for these points determined in ESRI ArcView 3.3 software. Refer to Appendix A for a complete description of aerial photo mosaic development and positional accuracy assessment.

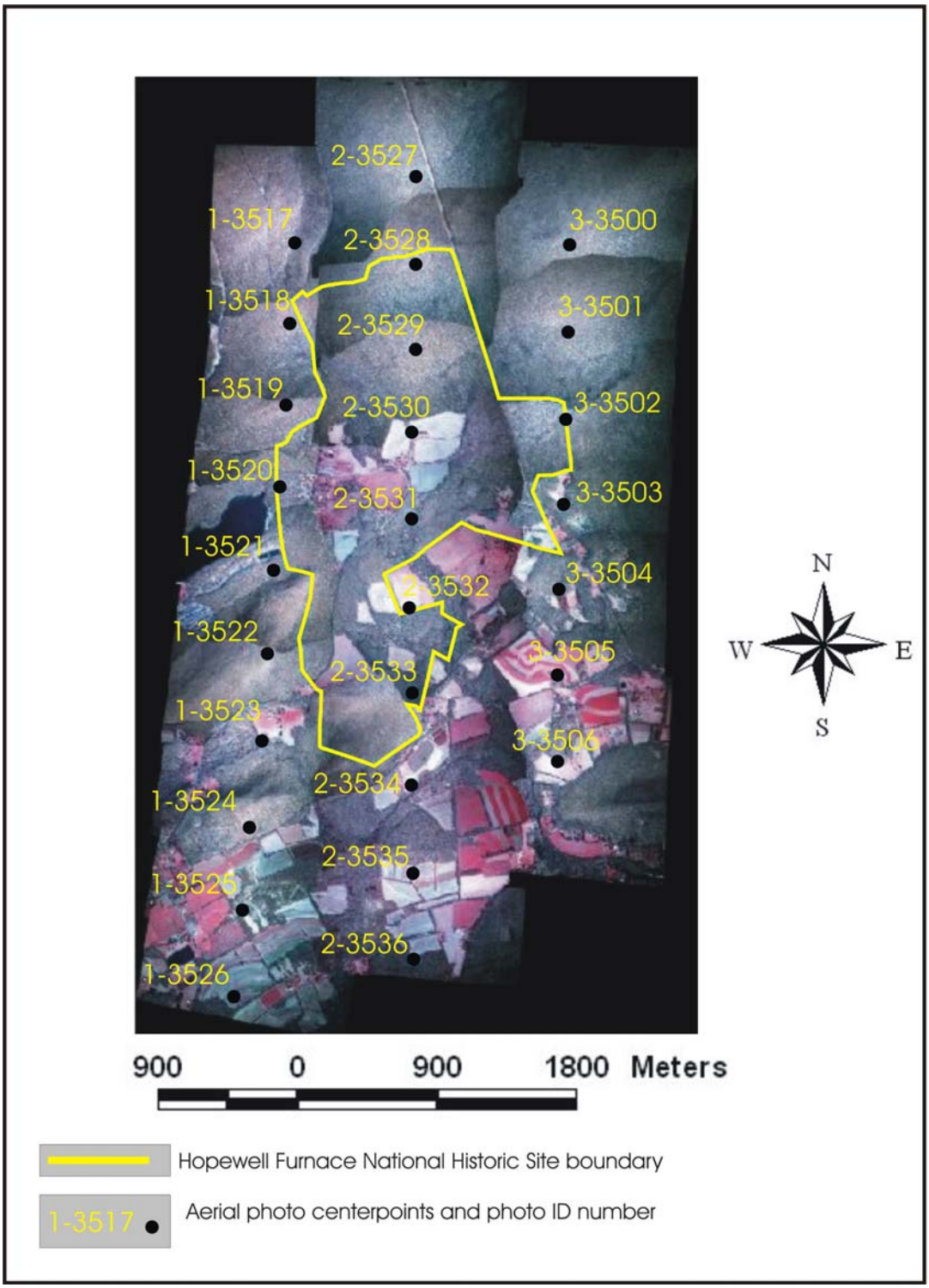


Figure 3. Location of aerial photography flight lines and centerpoints of individual photographs used to develop ortho-rectified digital photograph mosaic for Hopewell Furnace National Historic Site.

Air Photo Interpretation

The initial interpretation of the aerial photography delineates polygons to the formation level of the National Vegetation Classification System (NVCS). Formations, as defined in the NVCS, "represent vegetation types that share a definite physiognomy or structure within broadly defined environmental factors, relative landscape positions, or hydrologic regimes. Structural factors such as crown shape and lifeform of the dominant stratum are used in addition to the physiognomic characters already specified at the higher levels" (Grossman et al. 1998). Polygons are delineated and labeled based on signatures observed on the photography and information from preliminary field surveys and notes.

The alliance-level map was developed based on vegetation classification plot analysis and matching of resulting alliance-level classification of plots with the polygon sampled. Review of sampled polygons for each alliance allowed the development of a visual "signature" which allowed the classification of non-sampled polygons to the appropriate alliance. Polygons in the formation-level map were then reclassified with alliance names to generate the alliance-level map. Formation-level polygons were subsequently modified in the alliance-level map to reflect field observations made during vegetation classification sampling. Additional minor changes were made to the alliance-level map in response to the results of the accuracy assessment analysis.

Field Data Collection and Classification

Planning

Field work followed the methodology developed by The Nature Conservancy in conjunction with the USGS/NPS Vegetation Mapping Program (The Nature Conservancy 1994). The following is a summary of these methods as applied to Hopewell Furnace NHS.

Because Hopewell Furnace NHS is considered to be of "small size," the sample area includes the entire park. Decisions regarding number of plots and environmentally stratified plot placement were based on the whole park. By comparison, in large parks the plot placement and stratification is focused on only a section of the park, and results extrapolated to the whole.

Field Survey

The development of an alliance-level vegetation map requires quantitative information sufficient to identify and classify vegetation alliances. An alliance, as defined by the NVCS (Grossman et al. 1998), "is a physiognomically uniform group of plant associations sharing one or more dominant or diagnostic species, which as a rule are found in the uppermost stratum of the vegetation."

A total of 13 formation-level polygon types were initially identified in the park during air photo interpretation. Of these, six formations were considered anthropogenic, and three were not sampled (orchard, developed land, and transportation corridor). Orchards were limited to active apple orchards near the Hopewell Furnace NHS visitor center. Developed land included buildings and associated mowed lawns, and any other park infrastructure other than roads. Transportation corridors included roads and mowed shoulders as well as parking lots. Of the

remaining three (right-of-way, cropland, and medium-tall sod temperate or subpolar grassland), either quantitative plots were sampled or species lists developed. The seven "natural" formations (not directly impacted by routine human management/activity) were sampled by assigning one to 22 plots per formation distributed across the park. Twenty-two plots were sampled in the lowland or submontane cold-deciduous forest formation as it contained several alliances and covered approximately 70% of the park. Formations sampled only once typically were limited to a single small polygon within the park.

Vegetation Sampling

Plots were subjectively placed to be most representative of the vegetation within a given formation polygon. All mapped vegetation types were sampled over a range of environmental variation (primarily geology, hydrology, and topographic position) (see Appendix B for field data forms). Plot sizes were determined based on physiognomy: 20 x 20 m for forests and woodlands, 10 x 10 m for shrublands, and 5 x 5 m for herbaceous vegetation. Forest was defined as vegetation with trees over 5 m high and canopy cover between 60 to 100%. Woodland was defined as vegetation with trees over 5 m high and canopy cover 25 to 60%. Shrubland was defined as vegetation with trees and shrubs less than 5 m tall and typically more than 0.5 m tall with shrub cover greater than 25%. Herbaceous vegetation was defined as vegetation with herbs (graminoids, forbs, and ferns) dominant with woody plants (trees and shrubs) typically having less than 25% total cover. The vegetation was visually divided into strata, all the species of each stratum listed, and percent cover (in modified Braun–Blanquet cover classes) estimated for each. Vegetation strata used in sampling were emergent (individual trees significantly taller or emergent relative to the general height of the forest canopy), canopy (general forest canopy), subcanopy (trees with maximum height below general forest canopy, but taller than 5 m in height), tall shrub (saplings and shrubs 2 to 5 m in height), short shrubs (woody plants under 2 m in height), herbaceous (grasses, sedges, forbs, and ferns), vines and lianas (perennial woody vegetation with a vine habit), and non-vascular (mosses and lichens). Additional species within a formation ploygon that occurred outside of sampled plots 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: flooding regime, soil moisture regime, slope, aspect, and evidence of disturbance. Additional notes on plot setting, other environmental factors, surrounding stand, etc., were recorded as appropriate. Location of each plot was recorded using a differentially corrected GPS unit, with datum set to North America 1983 (Conus) and coordinate system set to Universal Trans-Mercator (UTM) Zone 18 North. The vegetation/topographic profile was sketched in cross-section to represent the location and setting of the plot. A digital photo was taken of each sample plot.

The Pennsylvania Science Office of The Nature Conservancy (PSO/ TNC) completed sampling of 35 plant community plots at the Hopewell Furnace National Historic Site between July and September 2002. A complete copy of original and transcribed field data sheets was sent to the NatureServe regional ecologist in Boston for use in developing crosswalks between park vegetation types and the National Vegetation Classification System.

Data Analysis

Plot data and existing vegetation information were used to develop a complete park-based vegetation list and identify floristic patterns across the park. Plot data were analyzed using multivariate statistics to identify relationships between vegetation plots and assign them to groups. These groups were then further reviewed and vegetation descriptions developed. Based on these descriptions, groupings were crosswalked to NVCS alliances, or if a crosswalk was not possible, a park-specific "alliance" was created (often necessary for altered or disturbed successional vegetation).

Park plot data (35 plots) were entered by PSO/TNC into the NatureServe PLOTS Database System (1997) on a Microsoft Access platform. The PLOTS database provides a stable, uniform database for archiving plant community data and allows data export into formats used by analytical software. Species were assigned standardized codes and names based on the PLANTS database developed by National Resources Conservation Service (NRCS) in cooperation with the Biota of North America Program (BONAP). Species and plot data for use in ordination and classification were exported from the PLOTS database and formatted into an Excel spreadsheet for use in the PC-ORD version 4.0 Multivariate Analysis package (McCune and Mefford 1999). PSO/TNC community ecologists ran preliminary analyses of the data using Detrended Correspondence Analysis (DCA) (Hill and Gauch 1980), Two-Way Indicator Species Analysis/TWINSPAN (Hill 1979), and Non-metric Multidimensional Scaling (NMS) (Kruskal and Wish 1978, Clarke 1993). DCA ordinates both species and samples simultaneously along vegetation gradients that reflect often complex environmental gradients (moisture, elevation, nutrients, etc.). TWINSPAN successively divides the plots into groups that are similar in species composition. NMS is an ordination method well suited to non-normal data sets. PSO/TNC ecologists reviewed the results and conducted further analyses with PC-ORD to assign plots to National Vegetation Classification System (Nature Serve 2002) alliances. In addition to runs of the larger set of plots, several subsets were selected and analyzed to gain further clarification.

The results were compared with the NVCS as well as to detailed descriptions specific to these alliances in the Lower New England–Northern Piedmont ecoregion (Lundgren 2000). Plots were matched to existing alliances whenever possible. Environmental data on slope, aspect, flooding regime, and topography for each plot were used to interpret the results. The geologic map, topographic maps, and polygon locations as delineated on the air photos were also used in the interpretation.

Vegetation Key

The vegetation key and detailed vegetation descriptions allow researchers and park resource managers to rapidly identify vegetation types in the field. The vegetation key and descriptions are also necessary for accurate vegetation evaluation during the map accuracy assessment phase.

A vegetation key was developed for the park after completion of the vegetation classification (Appendix C). Major classes in the key were based on either anthropogenic disturbance or management (including land actively managed for or by humans including buildings and associated lawns, transportation corridors, utility rights-of-way, orchards, cropland, and pasture) or vegetation physiognomic type (i.e., herbaceous, shrubland, woodland, and forest).

Herbaceous vegetation was defined as vegetation dominated by grasses and/or forbs with less than 25% cover of either trees or shrubs. Shrubland was defined by shrub cover greater than 25%, but tree cover less than 25%. Woodland was defined as tree cover 25 to 60% (shrub and herbaceous cover variable). Forest was defined by tree canopy cover greater than 60%. Each physiognomic type was further divided into terrestrial versus palustrine vegetation groups. Terrestrial and palustrine groups were then divided into subgroups or into individual alliances, depending upon characteristic canopy, subcanopy, shrub, and/or herbaceous species. Similar vegetation types were typically separated on the basis of percent cover of one or more diagnostic species.

The key included all vegetation types mapped in the park as well as one type known to occur in the park, but at a scale too small to map (e.g., Skunk Cabbage–Golden Saxifrage Forested Seep). Copies of the Hopewell Furnace NHS data in the PLOTS database (MS ACCESS format) and the PC-ORD-formatted data (MS EXCEL spreadsheet), as well as digital photography for each plot, were provided to NatureServe for the purpose of developing crosswalks between park vegetation types and the National Vegetation Classification System. Once crosswalks were established NatureServe ecologists provided PSO/TNC ecologists with global alliance-level descriptions for each vegetation type found in the park (Appendix D).

Thematic Accuracy Assessment Field Methods

Thematic accuracy assessment has several objectives including to assess the data's suitability for a particular application, to inform the map producers to learn more about data errors and improve the mapping process, and to conform to production standards.

The standard Accuracy Assessment (AA) protocol for Hopewell Furnace NHS was modified from a stratified random sampling approach to a complete census due to the small number of natural and semi-natural vegetation polygons (48 total). Polygon types not selected for AA sampling included areas lacking natural vegetation, (roads, lawns, buildings, and orchards), areas subject to grazing (wet and upland pastureland), or areas managed for power line rights-of-way. AA sampling coordinates were selected by generating 200 random points within the minimum and maximum easting and northing UTM coordinates of the park's extent. Points within 30 m of a polygon border were eliminated to avoid sampling within ecotones. If two or more points still remained in a polygon, one point was randomly chosen and the others discarded. In several of the larger polygons two or three points were selected for a total of 52 AA sampling points in 48 polygons. In the case of some smaller polygons, additional random point selection was required before a random point fell into those polygons. Also, in some polygons it was not possible to locate an AA point 30 m from a border, in which case the AA point was manually located equidistant from polygon borders.

AA points were located in the field using real-time differentially corrected GPS units (Trimble Pocket Pathfinder Receiver, Trimble Beacon-On-A-Belt unit, and Compaq iPAQ interface running TerraSync GPS software). Data collection (Appendix B) included accuracy assessment plot number and GPS location information, vegetation type at the AA point, vegetation type(s) within 50 m of the AA point, dominant species by strata, canopy closure, and rationale for classification. Vegetation alliances were identified using the vegetation key. AA results were analyzed using a sample misclassification matrix. Overall accuracy and the Kappa index were

calculated as described in the Accuracy Assessment Procedures–USGS/NPS Vegetation Mapping Program manual (Environmental Systems Research Institute et al. 1994).

Results

Vegetation Classification and Characterization

A total of 78 polygons were delineated at the formation level, 47 of which contained natural or semi-natural (e.g., pasture and grasslands) vegetation. From July through September 2002, PSO/TNC sampled a total of 35 plots (73% of the delineated natural and semi-natural community polygons) (Figure 4) to develop a vegetation classification for the park and to inform the development of the alliance-level vegetation map. Initial analyses in NMS and TWINSPAN identified six broadly defined vegetation groups: tulip poplar forest, dry oak–mixed hardwood forest, dry oak–heath forest, successional forest, palustrine shrublands, and palustrine forests (Figure 5). In addition, four vegetation plots were removed from the statistical analyses as they appeared to be outliers (plot 2 scrub/shrub vegetation along a right-of-way, plot 15 birch rocky slope woodland, plot 33 buttonbush wetland, and plot 35 grassland). Two of the outliers represent anthropogenic vegetation (plot 2 and plot 35) that is variable in composition and subject to routine management and disturbance (utility right-of-way management and cropland). The other two outliers (plot 15 and plot 33) represent vegetation alliances of very limited extent within the park. Three additional vegetation alliances, Modified Successional Woodland, Eastern Red Cedar Woodland, and Skunk Cabbage–Golden Saxifrage Forested Seep, were added based on field observations of a small disturbed successional hardwood stand, a small eastern red cedar woodland in an old field west of the visitors center, and several small forested seeps scattered throughout the park.

All but three vegetation types (Modified Successional Forest, Modified Successional Woodland, and Successional Scrub–Shrub) were matched to existing alliances in the National Vegetation Classification System. Twelve alliances were described at the park (see outline of the vegetation classification, below). Five of the alliances at Hopewell Furnace National Historic Site are classified as Forest ("Forest Class" in the National Vegetation Classification System hierarchy), three as Woodland, two as Shrubland, one as Grassland, and one as Forb. The park-specific vegetation alliance designated Successional Scrub–Shrub varied in physiognomic status from forb or shrubland to almost woodland, depending upon past right-of-way management history.

Local Alliance Descriptions

The following vegetation alliance descriptions are based on plot data and field observations at the Hopewell Furnace NHS. These types are treated as local expressions of the more widely occurring NVCS alliance to which they have been assigned. The NVCS alliance descriptions (Appendix D) are considered "global" descriptions and are based on observations across the entire geographic range of each alliance. As such, the NVCS alliance descriptions (as well as alliance names) may include species not found at Hopewell Furnace NHS. In addition, NVCS alliance descriptions are constantly being refined as more quantitative data becomes available from this and similar vegetation mapping and classification projects. A complete list of vascular plants found in the vegetation classification and accuracy assessment plots can be found in Appendix E. Some tree and shrub seedlings and immature herbaceous plants could only be identified to the genus level. Representative photos of each vegetation alliance can be found in Appendix F.

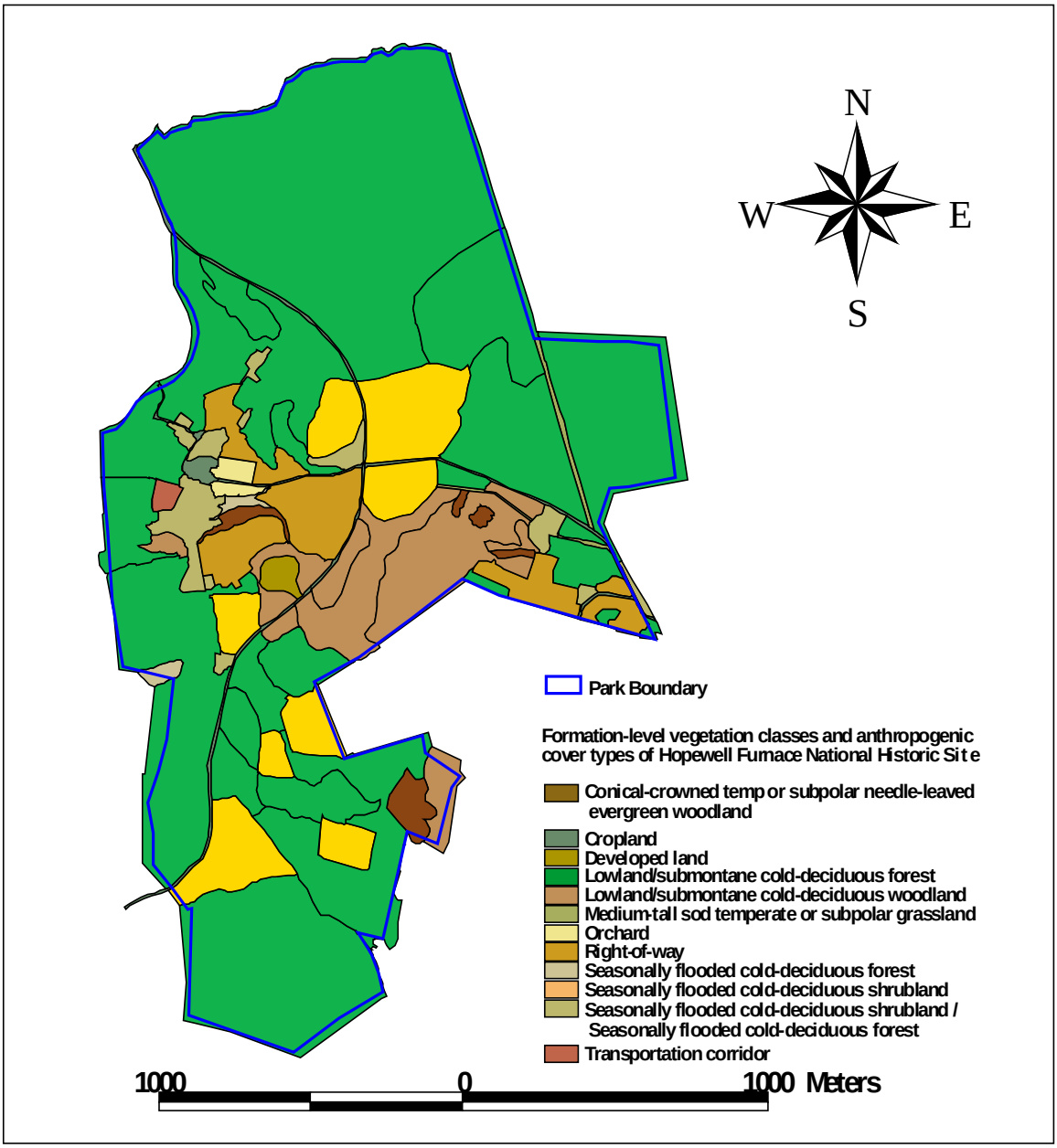


Figure 4. Location of vegetation classification sampling plots at Hopewell Furnace National Historic Site.

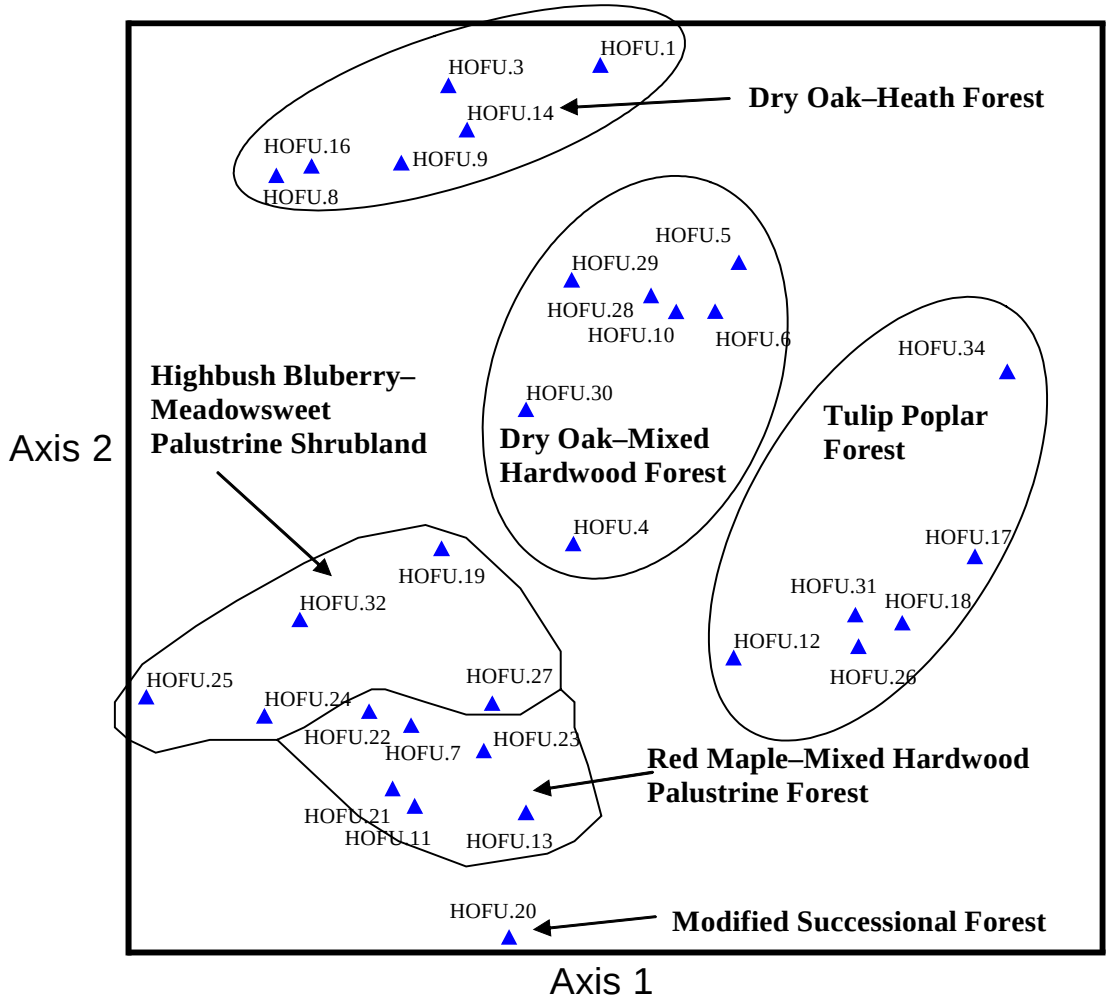


Figure 5. Graph of Non-metric Multi-dimensional Scaling (NMS) ordination of vegetation classification plot data. (Four plots were removed from analysis after being identified in prior analyses as outliers: plot 2 [scrub/shrub along powerline right-of-way], plot 15 [Birch Rocky Slope Woodland], plot 33 [Buttonbush Wetland], and plot 35 [Grassland].)

Tulip Poplar Forest
[NVCS Alliance: *Liriodendron tulipifera* Forest Alliance]

This type is found throughout Hopewell Furnace NHS as mid-successional and mature forest stands. The most characteristic feature of this type is the dominance of tulip poplar (*Liriodendron tulipifera*). Tulip poplar is the only dominant in many stands, with white ash (*Fraxinus americana*), beech (*Fagus grandifolia*), and big toothed aspen (*Populus grandidentata*) co-dominant or sub-dominant in others. Other occasional canopy trees include red maple (*Acer rubrum*), American elm (*Ulmus americana*), shagbark hickory (*Carya ovata*), and several species of oak (*Quercus* spp.). The subcanopy is usually open (typically less than 40% total cover), characterized by tulip poplar, red maple, white ash, beech, and American elm. Occasional individuals of flowering dogwood (*Cornus florida*), black gum (*Nyssa sylvatica*), black birch (*Betula lenta*), and sassafras (*Sassafras albidum*) are also present in the subcanopy. The shrub layer is also open and typically contains spicebush (*Lindera benzoin*), flowering dogwood, blackhaw (*Viburnum prunifolium*), and the nonnative species such as Japanese barberry (*Berberis thunbergii*) and wineberry (*Rubus phoenicolasius*). The herbaceous layer has very low diversity and is dominated by exotics. The herbaceous layer is typically a dense growth of stiltgrass (*Microstegium vimineum*), except in stands with a very dense canopy, in which case there may be a high proportion of bare ground. Other common herbaceous species include violets (*Viola* spp.), beaked agrimony (*Agrimonia rostellata*), wood sorrel (*Oxalis stricta*), and enchanter's nightshade (*Circaea lutetiana*). Bittersweet (*Celastrus orbiculatus*) and Japanese honeysuckle (*Lonicera japonica*), nonnative vines, often cover up to 60% of the ground in these stands as well as climbing nearly 20 m into the canopy.

Dry Oak–Heath Forest
[NVCS Alliance: *Quercus prinus*–(*Quercus coccinea*, *Quercus velutina*) Forest Alliance]

This type is most common on higher slopes and hilltops within Hopewell Furnace NHS. The canopy is dominated by drought-tolerant white oak (*Quercus alba*), chestnut oak (*Q. prinus*) scarlet oak (*Q. coccinea*), and black oak (*Q. velutina*), with red oak (*Q. rubra*) and black birch (*Betula lenta*) as occasional co-dominants. The subcanopy is characterized by moderate to dense cover of black gum (*Nyssa sylvatica*), black birch, red maple (*Acer rubrum*), sassafras (*Sassafras albidum*), and the aforementioned oak species. The shrub layer is often diagnostic for this type, characterized by moderate to dense cover of ericad species such as black huckleberry (*Gaylussacia baccata*), early low blueberry (*Vaccinium angustifolium*), lowbush blueberry (*Vaccinium pallidum)*, and pink azalea (*Rhododendron periclymenoides*). In some stands the tall shrub layer is dominated by young black gum and red maple. Herbaceous plants typically occur as solitary individuals or small clumps, when present. Common herbaceous species include partridgeberry (*Mitchella repens*), Canada mayflower (*Maianthemum canadense*), hay-scented fern (*Dennstaedtia punctilobula*), and Pennsylvania sedge (*Carex pensylvanica*). Catbriers (*Smilax glauca and S. rotundifolia*) are also typically present in low abundance.

Dry Oak–Mixed Hardwood Forest
[NVCS Alliance: *Quercus alba*–(*Quercus rubra*, *Carya* spp.) Forest Alliance]

Typically found on mid- to high slopes, these stands contain canopies dominated by black, red, and white oaks (*Quercus velutina, Q. rubra, and Q. alba*). Other hardwoods in the canopy include tulip poplar (*Liriodendron tulipifera*), red maple (*Acer rubrum*), black birch (*Betula lenta*), and pignut hickory (*Carya glabra*). These hardwoods are also found in the moderately dense subcanopy, which may also contain black gum (*Nyssa sylvatica*) and occasionally yellow birch (*Betula alleghaniensis*). Shrub species typically cover less than 30% of the stand and include flowering dogwood (*Cornus florida*), Japanese barberry (*Berberis thunbergii*), maple-leaved viburnum (*Viburnum acerifolium*) and witch-hazel (*Hamamelis virginiana*). Scattered ericad species, such as early low blueberry (*Vaccinium angustifolium*) and lowbush blueberry (*Vaccinium pallidum*) are also present, but not abundant. The herbaceous layer is patchy and frequently dominated by invasive species such as hay-scented fern (*Dennstaedtia punctilobula*) and Japanese stiltgrass (*Microstegium vimineum*). Other common herbaceous species include Pennsylvania sedge (*Carex pensylvanica*), shining bedstraw (*Galium concinnum*), and violets (*Viola* spp.). Virginia creeper (*Parthenocissus quinquefolia*) and poison ivy (*Toxicodendron radicans*) are also typically present in low abundance.

Modified Successional Forest
[No NVCS Alliance equivalent]

These stands are characterized by an open canopy dominated by early successional tree species including black walnut (*Juglans nigra*), American elm (*Ulmus americana*), and eastern red cedar (*Juniperus virginiana*). Other common canopy species include hickories (*Carya* spp.), white ash (*Fraxinus americana*), sassafras (*Sassafras albidum*), and black cherry (*Prunus serotina*). Tulip poplar (*Liriodendron tulipifera*) may also occur in these stands as an occasional to sub-dominant canopy species. The shrub layer is a mix of native and exotic species, including spicebush (*Lindera benzoin*), blackhaw (*Viburnum prunifolium*), multiflora rose (*Rosa multiflora*), tartarian honeysuckle (*Lonicera tartarica*), Morrow's honeysuckle (*Lonicera morrowii*), wineberry (*Rubus phoenicolasius*), and Japanese barberry (*Berberis thunbergii*). A characteristic feature of this vegetation type is a high cover of vines including fox grape (*Vitis labrusca*), Japanese honeysuckle (*Lonicera japonica*), and oriental bittersweet (*Celastrus orbiculatus*). The herbaceous layer is variable but typically has a high relative cover of nonnative species, especially Japanese stiltgrass (*Microstegium vimineum*).

Red Maple–Mixed Hardwood Palustrine Forest
[NVCS Alliance: *Acer rubrum–Fraxinus pennsylvanica* Seasonally Flooded Forest Alliance]

These young to mid-successional communities are found throughout Hopewell Furnace NHS in swales and other low-lying areas. Red maple (*Acer rubrum*) dominates the canopy, which also contains scattered green ash (*Fraxinus pennsylvanica*), pin oak (*Quercus palustris*), shagbark hickory (*Carya ovata*), and American elm (*Ulmus americana*). The sparse subcanopy is comprised of red maple, American elm, black gum (*Nyssa sylvatica*), white ash (*Fraxinus americana*), and ironwood (*Carpinus caroliniana*). Shrubs typically cover between 15-35% of the area. Common shrubs include blackhaw (*Viburnum prunifolium*), spicebush (*Lindera benzoin*), winterberry (*Ilex verticillata*), and shadbush (*Amelanchier arborea*). Nonnative shrub

species such as Japanese barberry (*Berberis thunbergii*), wineberry (*Rubus phoenicolasius*), and multiflora rose (*Rosa multiflora*) are also prevalent. The dominant herbaceous species in these communities is often stiltgrass (*Microstegium vimineum*), with associates including sweet woodreed (*Cinna arundinacea*), skunk cabbage (*Symplocarpus foetidus*), brome sedge (*Carex bromoides*), and jack-in-the-pulpit (*Arisaema triphyllum*). Vines such as fox grape (*Vitis labrusca*), Japanese honeysuckle (*Lonicera japonica*), and catbrier (*Smilax rotundifolia*) are typically abundant and may reach cover values of 30% and extend 20 m into the canopy.

Successional Scrub–Shrub (Powerline Right-of-Way Corridor)
[No NVCS Alliance equivalent]

This vegetation type occurs within the several power line rights-of-way within the national historic site. Tree species appear to be cut or herbicided within the rights-of-way to prevent interference with electrical power transmission, resulting in a disturbed early succession mix of herbs, vines, shrubs, and tree saplings. Since this vegetation is strongly influenced by the adjacent vegetation type or land use as well as topographic position, plant species composition is extremely variable and identification of characteristic species not practicable. However, it should be noted that invasive native and exotic species are often abundant within rights-of-way, including fox grape (*Vitis labrusca*), oriental bittersweet (*Celastrus orbiculatus*), Japanese honeysuckles (*Lonicera japonica*), multiflora rose (*Rosa multiflora*), and Japanese stiltgrass (*Microstegium vimineum*).

Birch Rocky Slope Woodland
[NVCS Alliance: *Quercus rubra–Quercus prinus* Woodland Alliance]

This type is limited to a small area in the southern portion of the national historic site where a steep, north-facing boulder scree slope occurs. The canopy is sparse (<60%) and dominated by scattered chestnut oak (*Quercus prinus*) and yellow birch (*Betula allegheniesis*). Red maple (*Acer rubrum*) may be present but is not dominant. The canopy is stunted, typically less than 15 to 20 m and a well-developed subcanopy is absent. The shrub layer is sparse and may include tree saplings (especially *B. alleghaniensis*) as well as serviceberry (*Amelanchier arborea*), highbush blueberry (*Vaccinium corymbosum*), and black huckleberry (*Gaylussacia baccata*). The herbaceous layer is also depauperate and characterized by rock polypoidy (*Polypodium virginianum*) in crevices between boulders where organic matter has accumulated. The boulders are typically covered by a dense growth of lichens and bryophytes.

Eastern Red Cedar Woodland
[NVCS Alliance: *Juniperus virginiana* Forest Alliance]

This type is limited to one small former pasture just north of the blast furnace building. The canopy is composed of well-spaced eastern red cedars (*Juniperus virginiana*) (possibly planted) with total cover well below 60%. There is little to no tall shrub layer and low short shrub cover. Typical low shrubs include multiflora rose (*Rosa multiflora*) and autumn olive (*Elaeagnus umbellata*). The herbaceous layer is similar to the Grassland type within the park, but has a somewhat higher cover of forb species.

Modified Successional Woodland
[No NVCS Alliance equivalent]

This alliance is very similar to the Modified Successional Forest alliance (see above for species composition and general description), but has lower tree cover (less than 60%).

Highbush Blueberry–Meadowsweet Wetland
[NVCS Alliance: *Vaccinium formosum–Vaccinium fuscatum* Seasonally Flooded Shrubland Alliance]

These wetland areas are dominated by shrubs, typically Southern arrowwood (*Viburnum dentatum*), winterberry (*Ilex verticillata*), smooth alder (*Alnus serrulata*), maleberry (*Lyonia ligustrina*), and highbush blueberry (*Vaccinium corymbosum*). Scattered trees of canopy and subcanopy height can also be found throughout the swamp. Red maple (*Acer rubrum*), American elm (*Ulmus americana*), green ash (*Fraxinus pensylvanica*), black gum (*Nyssa sylvatica*), and pin oak (*Quercus palustris*) are the most tree common species. The groundstory contains diverse herbaceous cover, including jewelweed (*Impatiens capensis*), arrowleaf tearthumb (*Polygonum sagittatum*), halberd-leaf tearthumb (*Polygonum arifolium*), climbing false buckwheat (*Polygonum scandens*), and eastern marsh fern (*Thelypteris palustris*). Several grass and sedge species, such as stiltgrass (*Microstegium vimineum*), rice cutgrass (*Leersia oryzoides*), shallow sedge (*Carex lurida*), melic mannagrass (*Glyceria melicaria*), and uptight sedge (*Carex stricta*) are also present.

Buttonbush Wetland
[NVCS Alliance: *Cephalanthus occidentalis* Seasonally Flooded Shrubland Alliance]

This vegetation type is limited to a single degraded example south of the park visitor center along French Creek. At HOFU, this type is characterized by large individual buttonbush (*Cephanlanthuss occidentalis*) plants in a seasonally wet portion of an active pasture. The soil is poorly drained mineral soil. The wetland has become weedy due to horse, cattle, and deer grazing and trampling disturbance. Characteristic species in the shrub layers include buttonbush (*Cephanlanthus occidentalis*), spicebush (*Lindera benzoin*), northern arrowwood (*Viburnum recognitum*), blackberry (*Rubus alleghanieinsis*), smooth alder (*Alnus serrulata*), and swamp rose (*Rosa palustris*). Vine cover is often very high with fox grape (*Vitis labrusca*), summer grape (*V. aestevalis*), oriental bittersweet (*Celastrus orbiculatus*), and Japanese honeysuckle (*Lonicera japonica*). The herbaceous layer is variable and is characterized by water-pepper (*Polygonum hydropiper*), stiltgrass (*Microstegium viminuem*), tussock sedge (*Carex stricta*), false stinging-nettle (*Boehmeria cylindrica*), and skunk cabbage (*Symplocarpus foetidus*).

Skunk Cabbage–Golden Saxifrage Forested Seep
[NVCS Alliance: *Symplocarpus foetidus–Caltha palustris* Saturated Herbaceous Alliance]

This community was not mapped, as it occurs in very small (much less than 0.5 ha, the minimum mapping unit) patches under partially- to completely-closed forest canopy. This alliance is characterized by perennial groundwater seepage and/or a locally high water table. The surrounding forest is typically wet to mesic (at Hopewell this includes Tulip Poplar Forest and Red Maple–Mixed Hardwood Palustrine Forest). This alliance is not associated with the oak-

dominated forests, as seeps are uncommon in those areas. The dominant vegetation varies by season, as skunk cabbage (*Symplocarpus foetidus*) is leafed out during the spring and early summer but may be completely dormant by late summer. Other typical species may include golden saxifrage (*Chrysosplenium americanum*), cinnamon fern (*Osmunda cinnamomea*), long sedge (*Carex folliculata*), partridgeberry (*Mitchella repens*), jewelweed (*Impatiens capensis*), fancy fern (*Dryopteris carthusiana*), Pennsylvania bitter-cress (*Cardamine pensylvanica*), clearweed (*Pilea pumila*), sweet-scented bedstraw (*Galium triflorum*), New York fern (*Thelypteris novaboracensis*), and sensitive fern (*Onoclea sensibilis*).

Grassland
[NVCS Alliance: *Dactylis glomerata–Rumex acetosella* Herbaceous Alliance]

This vegetation type is represented by hayfields at Hopewell Furnace. Only one vegetation classification plot was sampled in this type, though similar dominant species were noted during informal surveys of several other fields. Characteristic species include orchard-grass (*Dactylis glomerata*), sweet vernal grass (*Anthoxanthum odoratum*), foxtail-grass (*Setaria* spp.), horse-nettle (*Solanum carolinense*), and butter-and-eggs (*Linaria vulgaris*).

Vegetation Map Production

Photo interpretation was completed by PSO/TNC. From the mosaic, PSO/TNC delineated individual polygons on the computer screen representing distinct vegetation formations as defined by NVCS. Aerial photo stereo pairs were used as necessary to obtain finer image details during interpretation. PSO/TNC photo-interpreters also performed several informal surveys of the park to familiarize themselves with formations within the park before attributing formation names to mapping polygons. Formation signatures were developed based on aerial photointerpretation and informal park surveys as described below. A summary of polygon distribution and total area by formation is given in Table 1.

Formation signatures:

Anthropogenic Formations (non-NVCS types used to represent intensively managed or altered portions of the landscape):

1. Cropland: Cropland appeared as light pink to bluish open fields with no woody vegetation. Fields that had more recently been in field crops typically had clearly visible tractor/equipment ruts evident as evenly spaced, parallel lines. Some cropland had only weak evidence of tractor/equipment ruts and resembled grassland in aerial photography, but was reassigned to cropland at the guidance of NPS staff

2. Developed Land: Developed land included buildings and surrounding grounds (mowed grass) which usually had a medium to dark pink color that was fairly uniform in texture.

Table 1. A summary of the number and total area of anthropogenic and natural polygons for the Hopewell Furnace National Historic Site formation-level map.

Formation Name	Number of Polygons	Area (hectares)
Anthropogenic		
Cropland	8	32.77
Developed land	12	9.30
Orchard	2	1.61
Right-of-way	3	1.39
Transportation corridor	6	5.09
Medium-tall sod temperate or subpolar grassland	6	19.46
Natural		
Seasonally flooded cold-deciduous shrubland	4	3.25
Seasonally flooded cold-deciduous shrubland / forest	1	1.40
Temporarily flooded cold-deciduous shrubland	1	1.10
Conical-crowned temperate or subpolar needle-leaved evergreen forest	1	0.78
Lowland or submontane cold-deciduous woodland	2	1.32
Seasonally flooded cold-deciduous forest	9	30.56
Lowland or submontane cold-deciduous forest	23	251.63
Total	78	359.65

3. Orchard: Orchards were evident as open woodlands with evenly spaced trees and a uniform medium to dark pink ground layer (mowed grass).

4. Right-of-Way: The powerline right-of-way was evident as a narrow, linear band of low shrubby vegetation surrounded by forest. The right-of-way also contained scattered conifers (dark pink to red trees with conical crowns), while the ground layer appeared to be light pink to gray. The right-of-way was not mapped across cropland, as the vegetation signature was uniform across the field (i.e., presence of powerline was not reflected in cropland vegetation signature).

5. Transportation Corridor: Transportation corridor included all major and minor roads within the park, excluding roads used primarily for visitor foot traffic (included in "Developed Land"). Transportation Corridor also included parking areas, their adjacent medians, and mowed areas. Roads were evident as linear features, usually light to dark bluish-gray in color. Painted lines on roads and parking lots were readily seen.

6. Medium-tall Sod Temperate or Subpolar Grassland: Grasslands were characterized by a dark pink to light pink/white color, fairly uniform texture, and a lack of parallel lines. Woody vegetation is also lacking. The dark pink grasslands were areas of active pasture and were initially isolated as "Pasture" but were reclassified as grassland at the request of park staff. One of the pasture grasslands has evidence of dark parallel lines, but these appear to be artifacts of subsurface drainage tiles and not from tractor/equipment ruts as in the Cropland above. The light pink/white grasslands often had fine lines evident, but they were not parallel and appear to be evidence of trails made by deer and other animals.

Natural Formations:

1. Lowland or Submontane Cold-deciduous Forest: This formation covered much of the park and was characterized by closed tree canopies (crowns of trees touching or nearly so) and a generally light to medium pink or brownish pink understory. Use of hardcopy stereo pairs also helped identify swales and depressions (likely to be forested wetland) more properly classified below.

2. Conical-crowned Temperate or Subpolar Needle-leaved Evergreen Forest: This type only occurred in one small polygon near the visitor center. The signature was scattered red-dark pink conifers with very narrow crowns (eastern red cedars) with an open ground layer light pink/brown to white in color. Some clumps of shrubs also occurred in this type, appearing as low, mottled woody vegetation gray to grayish-brown.

3. Lowland or Submontane Cold-deciduous Woodland: This formation was characterized by two different signatures, reflecting two different alliances. One signature was open forest/woodland with well spaced trees and moderate to dense shrub layer evidenced by a mottled to nearly uniform gray on moderate to steep slopes. Some open grass/forb areas were also present as light to medium pink

patches. The second signature was quite different, characterized by widely spaced canopy trees over a dark blue-gray mottled ground layer. Using aerial photo stereo pairs, the groundlayer was resolved into a steep north-facing boulder field with an open canopy.

4. Temporarily Flooded Cold-deciduous Shrubland: This formation was limited to one polygon along French Creek, within an active pasture. The signature was complicated as a result of grazing disturbance, and the assignment at the formation level was primarily on the basis of ground-truthing. The signature consists of low shrub cover with a mottled blue-gray appearance interspersed with light bown to light pink groundcover between shrubs. The groundcover may also appear mottled, reflecting the abundant tussock sedge (*Carex stricta*). Some invasive shrubs (multiflora rose [*Rosa multiflora*] and/or Japanese barberry [*Berberis thunbergii*]) are present with a medium dark pink signature.

5. Seasonally Flooded Cold-deciduous Forest: The signature for this formation was a blue-gray to grayish-pink ground cover below a closed canopy, typically along meandering channels and small drainage ways. Review of aerial photo stereo pairs indicated that this type was associated with basins and the lower slope of broad, gentle rises. The dominant canopy tree was red maple, evidenced in the original photography as fairly symmetrical crowns with a white to light gray color.

6. Seasonally Flooded Cold-deciduous Shrubland: The signature for this formation was best distinguished using aerial photo stereo pairs. The canopy was typically open, with less than 25% cover. The shrub layer was variable and sometimes difficult to distinguish from photography (all of the polygons in this formation were ground-truthed). The ground layer was the best diagnostic, where sedges formed small tussocks that appeared in the photography as a fine-grained, light-colored (light brown to light pink) mottles. In very wet polygons the tussocks appeared against a dark blue background, indicating either shallow surface water or saturated soil. One polygon had a very light brown background, reflecting a thick sedge and grass thatch layer. All of the occurrences of this formation were in the context of adjacent seasonally flooded cold-deciduous forest and reflect wetter portions of swales and depressions within the surrounding forest.

7. Seasonally Flooded Cold-deciduous Shrubland/Forest: One polygon was assigned to a combination formation to reflect an area of the park where the signature indicated a complex mosaic of two different formations, the seasonally flooded cold-deciduous shrubland and the seasonally flooded cold-deciduous forest. The aerial photo signatures were a mosaic of these formations as described above.

Once the vegetation classification analysis was completed, local and NVCS alliance names were assigned to all polygons sampled. Based on the signatures of the named polygons and field observations, local and alliance names were assigned to the remaining polygons. In some instances NVCS formations contained only one alliance and the signature for the formation and

the alliance are identical. However, some formations contained two or more alliances and required the differentiation of signatures within a formation. A summary of natural alliance signatures is presented below. Where the formation and alliance signatures are identical, the reader is referred to the discussion of formation signatures above. All anthropogenic formations were carried over to the alliance classification unchanged and are not described below. A summary of the number of alliance-level polygons and total area by alliance is presented in Table 2.

Natural formations and corresponding alliance signatures:

1. Lowland or Submontane Cold-deciduous Forest: This formation contained four alliances and was the most difficult to separate.

    a. Dry Oak–Heath Forest: The canopy trees (primarily oaks) appear to have coarse open crowns, while the ground layer appears a light to medium grayish brown and somewhat darker than the ground layer associated with the Dry Oak–Mixed Hardwood Forest. The slightly darker ground layer is evidence of moderate to dense low ericad (heath) shrub cover. The slightly darker ground layer may also represent a more bouldery substrate, particularly in the southwest corner of the park. Bedrock geology also helped distinguish the Dry Oak–Heath Forest from the Dry Oak–Mixed Hardwood Forest. Dry Oak–Heath Forest was restricted to the Cambrian and Precambrian quartzite and gneiss on low hills in the southern portion of the park, while the Dry Oak–Mixed Hardwood Forest was limited to the sandstone and quartzite conglomerate on hills and upper slopes in the northern portion of the park.

    b. Dry Oak–Mixed Hardwood Forest: The signature is similar to the Dry Oak–Heath above, with coarse crowns of oaks apparent, but the ground layer is lighter (light, uniform grayish brown), reflecting persistent oak leaf litter. A few boulder fields are present and will give the ground layer a somewhat darker, dappled texture. These typically occur as inclusions. The canopy signature will also contain a significant number of finer textured crowns with light gray twigs indicating other hardwood species, especially red maple and tulip poplar.

    c. Tulip Poplar Forest: The signature for this alliance included a variable ground layer, often with light to dark gray mottles over a medium gray-brown background, representing low to high shrub cover including spicebush, multiflora rose, and Japanese barberry. The darker ground layer may also reflect the higher cover of stiltgrass (annual grass resulting in bare ground by early spring) and lower amounts of persistent leaf litter (resulting in a lower albedo). The canopy, when distinguishable from ground layer, consists of fine-textured crowns with light gray twigs. This alliance tended to occur at mid- to low-slope position but not in wet depressions or swales.

Table 2. A summary of the number of polygons and total area by alliance for the final alliance-level vegetation map for Hopewell Furnace National Historic Site.

Local Alliance Name	Number of Polygons	Area (hectares)
Anthropogenic		
Cropland	8	32.77
Developed Land	12	9.30
Orchard	2	1.61
Right-of-way	3	1.39
Transportation corridor	6	5.09
Grassland	6	19.46
Natural and semi-natural		
Buttonbush Wetland	1	1.10
Highbush Blueberry–Meadowsweet Wetland	4	3.25
Highbush Blueberry–Meadowsweet Wetland / Red Maple–Mixed Hardwood Palustrine Forest	1	1.40
Eastern Red Cedar Woodland	1	0.78
Modified Successional Woodland	1	0.57
Birch Rocky Slope Woodland	1	0.75
Modified Successional Forest	4	8.34
Red Maple–Mixed Hardwood Palustrine Forest	9	30.56
Dry Oak–Heath Forest	4	60.41
Dry Oak–Mixed Hardwood Forest	9	142.53
Tulip Poplar Forest	6	40.35
Total	78	359.65

d. Modified Successional Forest: This alliance was variable in species composition but had several unifying characteristics in the aerial photo signature. The forest appears to be dominated by younger trees (often lower height than mature forest, with smaller diameters), canopy crowns are often small, and scattered eastern red cedars are common (appear dark pink-red with narrow conical crowns). Tulip poplars and red maple are common in this alliance and have light gray, fine-textured crowns. Some crowns may appear denser than normal due to heavy infestations of vines (e.g., oriental bittersweet [*Celastrus orbiculatus*] and grapes [*Vitis* spp.]). Canopy gaps are common. The ground layer appears mottled and varies from light pink-brown (mostly herbaceous cover) to a medium ash gray (shrub and dense vine cover).

2. Conical-crowned Temperate or Subpolar Needle-leaved Evergreen Forest:

   Eastern Red Cedar Woodland: This type only occurred in one small polygon near the visitor center. The signature was the same as for the formation as previously described.

3. Lowland or Submontane Cold-deciduous Woodland:

   a. Modified Successional Woodland: The signature was similar to the Modified Successional Forest but with lower tree canopy cover. The signature was characterized by well-spaced trees and moderate to dense shrub layer evidenced by a mottled to nearly uniform gray on moderate to steep slopes. Some open grass/forb areas were also present as light to medium pink patches. This alliance was mapped in only one polygon.

   b. Birch Rocky Slope Woodland: The signature for this alliance was characterized by widely-spaced canopy trees over a dark blue-gray mottled groundlayer. Using aerial photo stereo pairs, the groundlayer was resolved into a steep north-facing boulder field with an open canopy. This alliance was restricted to a single polygon.

4. Temporarily Flooded Cold-deciduous Shrubland:

   Buttonbush Wetland: This alliance was limited to one polygon along French Creek, within an active pasture. The signature was the same as for the formation as previously described.

5. Seasonally Flooded Cold-deciduous Forest:

   Red Maple–Mixed Hardwood Palustrine Forest: The signature for this alliance was the same as for the formation as previously described.

6. Seasonally Flooded Cold-deciduous Shrubland:

   Highbush Blueberry–Meadowsweet Wetland: The signature for this alliance was the same as for the formation as previously described.

7. Seasonally Flooded Cold-deciduous Shrubland/Forest:

   Highbush Blueberry–Meadowsweet Wetland/Red Maple–Mixed Hardwood Palustrine Forest: The signature for this combined alliance is the same as for the combined formation as previously described.

Accuracy Assessment

Positional Accuracy Assessment

Positional accuracy assessment of 12 reference points in the aerial photomosaic used to develop the vegetation map, as reported by the North Carolina State University–Center for Earth Observation, were conducted and the horizontal positional accuracy results were:

X-coordinate accuracy +/- : 1.18 meters
Y-coordinate accuracy +/- : 0.76 meters
Overall Positional Accuracy: 1.27 meters.

Positional accuracy meets the NMAS Class 1 map standard for X and Y. Positional accuracy assessment meets requirements for the USGS/NPS Vegetation Mapping Program (Appendix A).

Thematic Accuracy Assessment

Thematic accuracy assessment results are summarized in Table 3. Of the 52 accuracy assessment points sampled (Figure 6), the vegetation at 47 points was mapped correctly, giving an overall accuracy of 90.38%. The Kappa index (which corrects for correct classifications occurring by chance) was 88.77% ± 8.16% (90% C.I.). The vegetation at five points was mapped incorrectly based upon the vegetation key developed for the park (Appendix C). Two sample points (10 and 11) mapped as Tulip Poplar Forest keyed out to Modified Successional Forest. Sample point 29 was mapped as Dry Oak–Mixed Hardwood Forest and keyed out to Tulip Poplar Forest. Sample point 9 was mapped as Dry Oak–Heath Forest and keyed out to Dry Oak–Mixed Hardwood Forest. Sample point 46 was mapped as Red Maple–Mixed Hardwood Palustrine Forest and keyed out to Tulip Poplar Forest. Four out of the five incorrectly mapped polygons involved stands with significant amounts of *Liriodendron tulipifera*.

Final Alliance-Level Map

The alliance-level map was revised to resolve incorrectly mapped polygons as indicated by the AA (Figure 7). Polygons containing AA points 10 and 11 were reclassified as Modified Successional Forest after review of aerial photos and vegetation classification plot data. The area around AA point 29 was re-evaluated (using aerial photography) and a portion of the polygon reclassified as Tulip Poplar Forest. The polygon containing AA point 9 was reclassified to Dry Oak–Mixed Hardwood Forest based on aerial photos and accuracy assessment data

Table 3. Results of thematic accuracy assessment sampling at Hopewell Furnace National Historic Site.

	Alliance-Level Vegetation Map Designation											
Accuracy assessment observation	Acer rubrum–Fraxinus pennsylvanica seasonally flooded forest alliance	Cephalanthus occidentalis seasonally flooded shrubland	Dactylis glomerata–Rumex acetosella herbaceous alliance	Eastern Red Cedar woodland	Liriodendron tulipifera forest alliance	Modified Successional Forest	Quercus alba–(Quercus rubra, Carya spp.) forest alliance	Quercus prinus–(Quercus coccinea, Quercus velutina) forest alliance	Quercus rubra–Quercus prinus woodland alliance	Vaccinium formosum–Vaccinium fuscatum seasonally flooded shrubland allian	Total	Percent Correct
Acer rubrum–Fraxinus pennsylvanica seasonally flooded forest alliance	9										9	100.00
Cephalanthus occidentalis seasonally flooded shrubland		1									1	100.00
Dactylis glomerata–Rumex acetosella herbaceous alliance			8								8	100.00
Eastern Red Cedar woodland				1							1	100.00
Liriodendron tulipifera forest alliance	1				5		1				7	71.43
Modified Successional Forest					2	3					5	60.00
Quercus alba–(Quercus rubra, Carya spp.) forest alliance							10	1			11	90.91
Quercus prinus–(Quercus coccinea, Quercus velutina) forest alliance								4			4	100.00
Quercus rubra–Quercus prinus woodland alliance									1		1	100.00
Vaccinium formosum–Vaccinium fuscatum seasonally flooded shrubland allian										5	5	100.00
Total	10	1	8	1	7	3	11	5	1	5	52	
Percent correct	90.00	100.00	100.00	100.00	71.43	100.00	90.91	80.00	100.00	100.00		

Total Points Correct	47
Percent correct	90.38%
Kappa Index	88.77%
90% C.I. for Kappa Index	± 8.16%

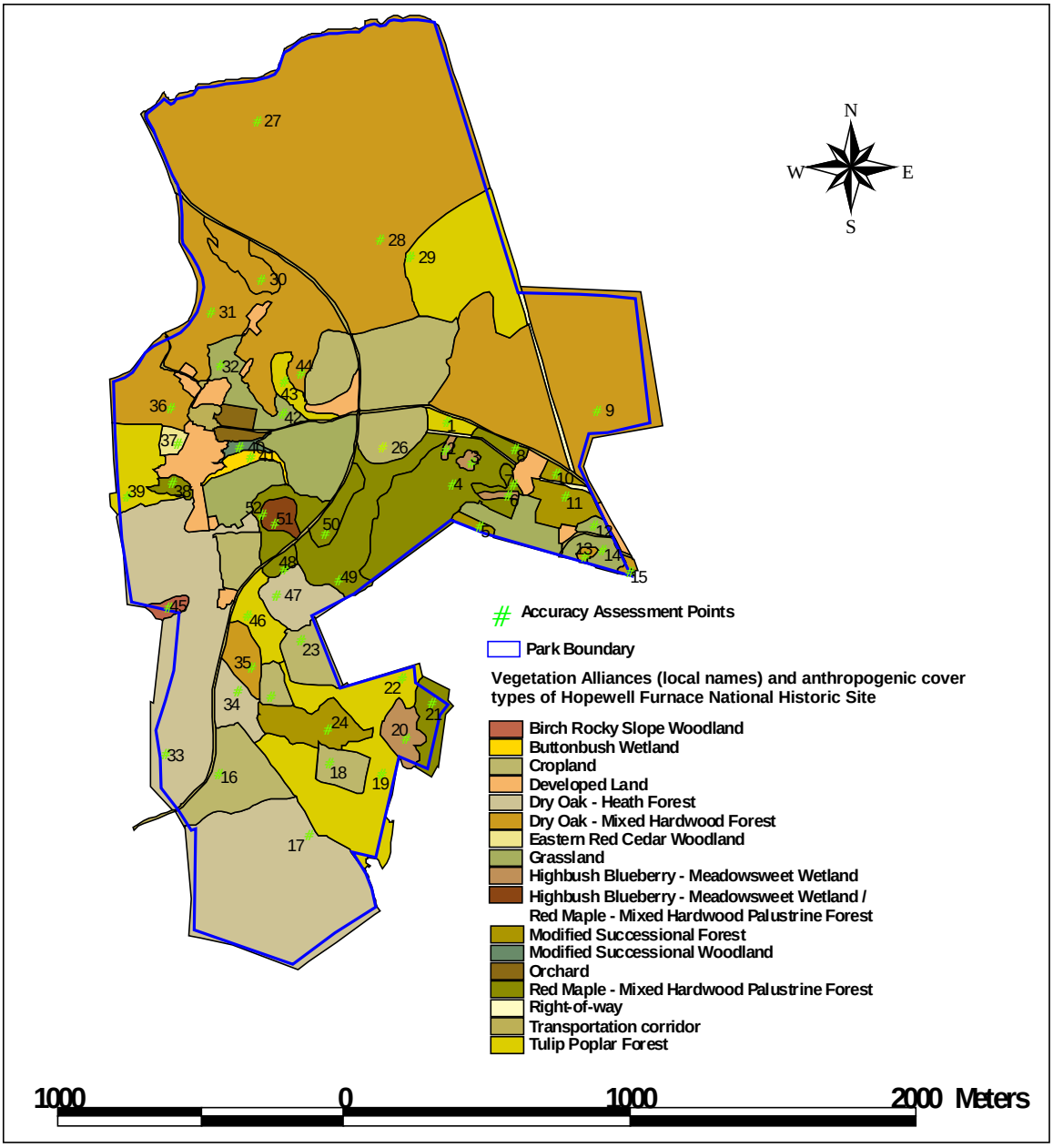


Figure 6. Thematic accuracy assessment sampling locations at Hopewell Furnace National Historic Site.

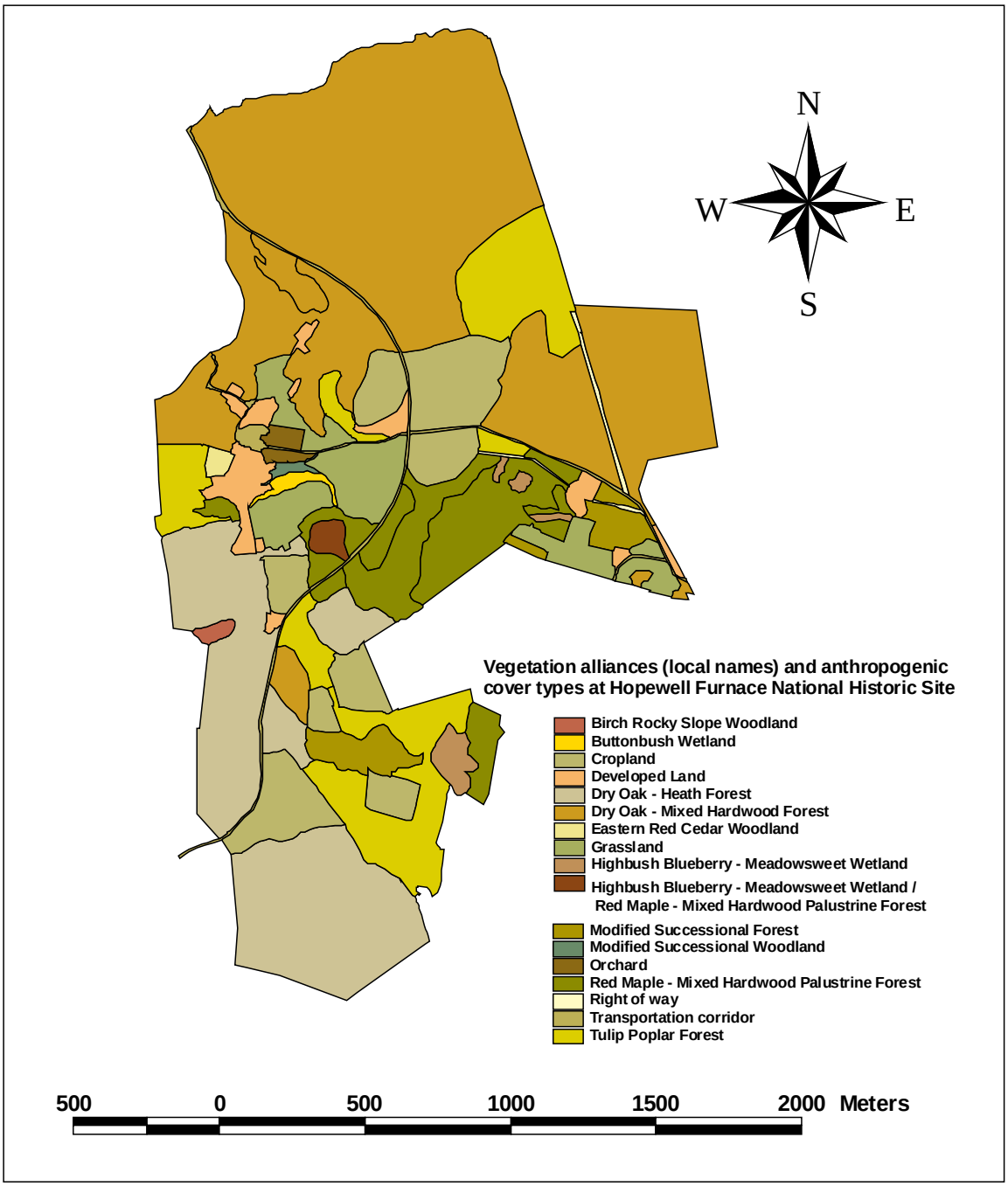


Figure 7. Final alliance-level vegetation map for Hopewell Furnace National Historic Site.

indicating low ericad cover and presence of non-ericaceous shrubs. The polygon at AA point 46 was reclassified as Tulip Poplar Forest based on aerial photos and a re-examination of vegetation classification plot data. Classification plot data (classification plot 9) from near AA point 46 was collected in a forested seep (5 m x 5 m herbaceous plot) and should not have been used to classify the polygon. After the corrections were made, all AA points should be in agreement with the revised alliance-level map polygons.

Project Deliverables

Final products of the vegetation mapping project are shown in Table 4. All products will be delivered to the National Park Service by the Pennsylvania Science Office of The Nature Conservancy with this report.

Table 4. Summary of products resulting from Hopewell Furnace National Historic Site vegetation mapping project.

Product	FGDC-compliant spatial metadata
Aerial photos, including flight line map and photoindex	Yes
Photomosaic as paper copy and digital format	Yes
Annotated field survey forms with plot data	Not applicable
Verified vegetation plot survey data (in TNC PLOTS format) with differentially corrected GPS geographic coordinates	Yes
Annotated field forms of AA data	Not applicable
Accuracy assessment (AA) data in Access format with differentially corrected GPS geographic locations	Yes
Digital photos representative of all vegetation types	Not applicable
Database of photo information in Access format	Yes
Final map of vegetation associations in digital and paper copy (digital copy as GIS layer in ArcView 3.2 format)	Yes
Final report in paper and digital formats	Not applicable

Discussion

Vegetation Classification and Characterization

Hopewell Furnace National Historic Site is located in Berks and Chester counties, within the Northern Piedmont ecological region. The vegetation is closely aligned with vegetation types described in the nearby states of Maryland, Delaware, and New Jersey. The distribution and character of vegetation within the park are most influenced by the underlying geology (and resulting geomorphology) and the history of human land use. All of the pre-European vegetation within the park was removed or altered during the clearing and development of the iron plantation over the 18th and 19th centuries. The cessation of iron-making just prior to the 20th century has allowed the redevelopment of forest on portions of the park (especially the northern and southern thirds). Agricultural activity has continued to the present in the center third of the park, though a few areas appear to have been abandoned in the past several decades.

Geology influences vegetation throughout the park by affecting soil development and landscape morphology. The northern and southern thirds of the park are underlain by weathering-resistant bedrock, favoring the development of low hills with thin, rocky soils. The center of the park consists of much weaker, easily eroded bedrock through which French Creek and several small tributaries flow. Soils in the center of the park are deeper, more fertile, and more mesic. The soils adjacent to French Creek are often flooded or seasonally saturated.

The distribution and character of vegetation within the park reflect the land use and geology as discussed above. The Dry Oak–Heath and Dry Oak–Mixed Hardwood forests are restricted to the dry hills in the north and south ends of the park. These forests were cleared to produce charcoal for use at the Hopewell iron furnace. Development of the present-day stands began shortly after the furnace ceased operations in the late 19th century. The general composition of these stands is typical of these forest types in Pennsylvania (Fike 1999), suggesting that these areas were not converted to other vegetation types (e.g. pasture) after clearing, but were allowed to regenerate to dry oak forests.

The vegetation in the center of the park is much more variable. Along the French Creek floodplain the soils appear to be at least seasonally saturated, favoring red maple-dominated forests. Most of the red maple stands appear to have been cropped or pastured in the past (evidenced by old stone walls and fence rows). Associated with the red maple forests are small pockets of shrub swamps and occasional wet herbaceous openings (especially along French Creek).

The tulip poplar-dominated stands occur along the toe slopes and lower slopes of hills in the park, and typically grade into the oak forests at higher elevations. The general size and age of these stands suggest they originated at about the same time as the oak forests. One notable exception is the tulip poplar stand due west of the furnace building, which appears to be a much younger successional stand on former agricultural land.

Grasslands within the park are anthropogenic in origin and are maintained as hayfields. Species composition reflects a mix of native and exotic grasses, sedges, and mostly weedy forb species.

Particular mapping problem areas were the differentiation between Dry Oak–Mixed Hardwood Forest and Tulip Poplar Forest, and between open Red Maple–Mixed Hardwood Forest and Highbush Blueberry–Meadowsweet Wetland. The Dry Oak–Mixed Hardwood Forest may contain a significant number of canopy tulip poplar as well as small patches of Tulip Poplar Forest (below minimum mapping area of 0.5 ha). The critical difference between the two types is the relatively high abundance of oaks in the Dry Oak–Mixed Hardwood Forest, where tulip poplar may be a co-dominant versus the low abundance of oaks in the Tulip Poplar Forest. In addition, shrubs typical of the Dry Oak–Mixed Hardwood Forest, such as maple-leaved viburnum, witch-hazel, and blueberries, are rare or absent from Tulip Poplar Forests. In contrast, Tulip Poplar Forests often have a much higher abundance of weedy exotic and native species (e.g., spicebush, multiflora rose, and Japanese barberry) in the shrub layer. The herb layer is also more well developed in the Tulip Poplar Forest, while it is usually sparse or absent from the Dry Oak–Mixed Hardwood Forest.

The Red Maple–Mixed Hardwood Forest often occurs adjacent the Highbush Blueberry–Meadowsweet Wetland, and may present some identification problems as one alliance tends to grade into the other as the soils become wetter. Differentiation between the two alliances relies on a judgment of tree canopy cover. Below 60% canopy cover the Red Maple–Mixed Hardwood Forest may more properly be referred to as a woodland. When the canopy cover falls to below 20% the dominant strata becomes the shrub layer, at which point the vegetation would be classified as Highbush Blueberry–Meadowsweet Wetland (assuming the prerequisite species are present).

Since the park is small and very accessible, much of the park was ground-truthed directly to distinguish between the types. In addition, information from the accuracy assessment was utilized to correct mapping errors related to the types above. The accuracy assessment also identified a misclassification of two Tulip Poplar Forest stands that should have been mapped as Modified Successional Forest. Re-evaluation of aerial photography, classification plot data sheets, and accuracy assessment data supported changing the polygons to Modified Successional Forest.

Invasive and exotic plant species are prevalent in some stands at Hopewell Furnace NHS. The Modified Successional Forest type is characterized by a high incidence of weedy species, particularly nonnative honeysuckles (*Lonicera* spp.), oriental bittersweet (*Celastrus orbiculatus*), grapes (*Vitis* spp.), and Japanese stiltgrass (*Microstegium vimineum*). Other vegetation types prone to invasive and exotic plant colonization include red maple stands, Tulip Poplar Forest, and the shrub wetlands. Wetlands along French Creek have been heavily impacted by these species. Invasive and exotic species are less of a problem in oak-dominated forests, perhaps due to the poor, droughty nature of the soils.

White-tailed deer impacts within the park appear to be significant. Most forest stands have few tree seedlings or saplings under 2 m in height. In some oak stands the only significant ground layer vegetation is hay-scented fern (*Dennstaedtia punctilobula*) and New York fern (*Thelyptris noveboracensis*), both of which are avoided by deer (Horseley 1992). Deer may also be a contributing factor to the weedy nature of the Modified Successional Forest stands by heavily browsing desirable native species and avoiding the invasive/exotic species (e.g., exotic honeysuckles, oriental bittersweet, and stiltgrass).

The global ranks of most of the vegetation types at Hopewell Furnace National Historic Site have not been defined as data on the extent of these communities is incomplete. None of the associations is considered to be rare, as they have all been documented from a number of locations in Pennsylvania. Data from this project will help to further refine the range-wide descriptions, extent, and global ranks of all of these vegetation associations.

Map Production

Identification and delineation of map polygons was fairly simple for most of the Hopewell Furnace NHS. One issue that arose was the relative inaccuracy of the available GIS park boundary files. Several boundary files available from the park or archived at North Carolina State University were in error by 10 to 25 m when overlaid on the digital ortho-photo mosaic. The boundary was later verified by Pennsylvania Science Office staff, who collected GPS coordinates for park boundary monuments. The resulting boundary (when GPS data was converted to a shapefile) was in close agreement with features observed in the photo mosaic (e.g. boundary roads, trails, hedgerows along property lines, etc.) and is considered the best representation of the park boundary for this mapping effort.

References Cited

Association for Biodiversity Information. 2000. International classification of ecological communities. Natural Heritage Central Databases: Valley Forge Subset Dec 2000. The Association for Biodiversity Information, Arlington VA and The Nature Conservancy / ERO, Boston MA.

Bowersox, T. W. and D. S. Larrick. 1999. Long-term monitoring of forested ecosystems at Valley Forge National Historic Park and Hopewell Furnace National Historic Site. Unpubl. Technical Report NPS/PHSO/NRTR-99/077. National Park Service, Philadelphia Support Office, Philadelphia PA.

Braun, E. L. 1950. Deciduous Forests of Eastern North America. The Free Press, Macmillan Publ. Co., New York.

Clarke, K. R. 1993. Non-parametric multi-variate analyses of changes in community structure. Australian Journal of Ecology 18: 117-143.

Fike, J. 1999. Terrestrial and Palustrine Plant Communities of Pennsylvania. Pennsylvania Department of Conservation and Natural Resources, Harrisburg, PA.

Grossman, D. H., D. Faber-Langendoen, A. S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International Classification of Ecological Communities: Terrestrial Vegetation of the United States (draft). The Nature Conservancy, Arlington VA.

Hill, M. O. 1979. TWINSPAN–A FORTRAN Program for Arranging Multivariate Data in an Ordered Two-way Table by Classification of the Individuals and Attributes. Cornell University. Ithaca, NY.

Hill, M. O. and H. G. Gauch. 1980. Detrended correspondence analysis: an improved ordination technique. Vegetatio 42: 47-58.

Horseley, S. B. 1992. Impact of deer on interactions among plants (abstract). in *Deer Density Effects on a Forested Ecosystem: a Pennsylvania Story; Results of a Ten-year Study.* Society of American Foresters. Warren, PA.

Kartesz, J. T. 1994. A Synonymized Checklist of the Vascular Flora of the United States, Canada, and Greenland. 2nd edition. 2 vols. Timber Press, Portland, OR.

Krusgal, J. B. and M. Wish. 1978. Multidimensional Scaling. Sage Publications, Beverly Hills, CA.

Lundgren, J. A., editor. 2000. Plant Communities of the Lower New England-Northern Piedmont ecoregion. Unpubl. report to The Nature Conservancy, Conservation Science Office, Boston, MA.

References Cited (continued)

McCune, B. and M. J.Mefford. 1999. PC-ORD. Multivariate Analysis of Ecological Data, Version 4.0. MjM Software Design, Gleneden Beach, OR..

Monk, C. D., D. W. Imm, and R. L. Potter. 1990. Oak forests of eastern North America. Castanea 55(2):77-96.

NatureServe: An online encyclopedia of life [web application]. 2001. Version 1.4. Arlington Virginia: Association for Biodiversity Information. Available: http//www.natureserve.org.

Opplinger, C. S. and R. Halma. 1988. The Poconos: An illustrated Natural History Guide. Rutgers University Press, New Brunswick, NJ.

Root, S. I. and D. B. MacLachlan. 1999. Gettysburg-Newark Lowland. In: Special Publication 1: The Geology of Pennsylvania, C. Shultz (Ed.),. Geological Survey of Pennsylvania, Harrisburg, PA.

The Nature Conservancy. 1994. NBS/NPS Vegetation Mapping Program. Unpubl. report. The Nature Conservancy, Arlington VA.

The Nature Conservancy. 1995. NBS/NPS Vegetation Mapping Program: Vegetation Classification of Assateague Island National Seashore. The Nature Conservancy, Eastern Regional Office, Boston, MA.

The Nature Conservancy. 1997. PLOTS Database System, Version 1.1. The Nature Conservancy, Arlington, VA.

Appendix A. Procedures used to develop a digital orthophoto mosaic for Hopewell Furnace National Historic Site.

Appendix A. Procedures used to develop a digital orthophoto mosaic for Hopewell Furnace National Historic Site.

Color infrared, stereo pair 1:6,000 scale aerial photography for a digital orthophoto mosaic of Hopewell Furnace National Historic Site was acquired from an overflight on April 4, 2002 (i.e., during leaf-off conditions) by Kucera International. The photography was delivered to the National Park Service (NPS), quality checked, accepted as provided, and sent to North Carolina State University (NCSU). Upon receipt at NCSU, the air photos were counted to make sure that none were missing, scanned, and placed in the air photo archive maintained at NCSU for the NPS Northeast Region Inventory & Monitoring Program. Associated data and information provided by Kucera, and also stored in the air photo archive, include the airborne GPS/IMU files, the camera calibration certificate for the camera, and the hardcopy flight report for the photography that crosswalks the airborne GPS/IMU data to the photo frame numbers.

The mosaic was produced from 25 color infrared air photos scanned at 600 dpi with 24-bit color depth. The scanned images of the air photos were imported into ERDAS Imagine (.img) format where a photo block was created using airborne GPS and IMU data that Kucera International supplied with the aerial photography. The photo block was manipulated until it could be triangulated with a root mean square error of less than 1. At this point, single frame orthophotos (one for each air photo) were generated within Imagine and exported to Imagine .lan format. Then the .lan files were imported into ER Mapper's native (.ers) format, and an ER Mapper algorithm was created which contains the color balancing information and the cutlines created for the final mosaic. In ER Mapper a band interleaved by line (.bil) image and header file of the final mosaic was generated, the .bil image was imported into Imagine .img format, and, finally, the .img image was compressed using MrSID software with a 20:1 compression ratio.

The horizontal positional accuracy of the mosaic was assessed using guidelines of the USGS/NPS Vegetation Mapping Program (ESRI, NCGIA, and TNC 1994). Well-defined positional accuracy ground control points, spaced throughout all quadrants of the mosaic, were placed on the final mosaic in ArcMap. Ground control points and zoomed-in screenshots of each point were plotted on hard copy maps with the mosaic as a background. These maps and plots were used to locate the ground control points in the field. For each plotted ground control point, field staff noted any alterations to the locations in the field, and then recorded the coordinates with a Trimble Pro XR/XRS or GeoXT. Mapped ground control points that were physically inaccessible were also noted. The field crew correctly located and collected accuracy assessment data at 13 ground control points.[1] The coordinate data were collected with real time GPS and post processed with differential correction using Pathfinder Office software. Prior to calculating accuracy, one ground control point, identified as an outlier with SAS's JMP program, was removed. For each of the remaining 12 points, the field-collected "true" or "reference" GPS coordinates were compared to the coordinates obtained from the mosaic viewed in ArcMap. Both pairs of coordinates for each point were entered into a spreadsheet in order to calculate horizontal accuracy (in meters). Figure A1 shows the distribution of these 12 ground control points within the park and surrounding area.

The final horizontal positional accuracy for the mosaic is 1.27 meters and meets Class 1 National Map Accuracy Standards (FGDC 1998b). A copy of the spreadsheet that contains the x and y coordinates for each ground control point and the Euclidean distance accuracy calculation formula is included in the air photo archive.

[1] USGS/NPS Vegetation Mapping Program guidelines recommend a minimum of 20 ground control points for accuracy assessment regardless of park size. In this case, we did not meet that guideline because of technical problems with the GPS equipment and time constraints.

A metadata record for the mosaic was prepared according to current Federal Geographic Data Committee standards (FGDC 1998a). Metadata were produced in notepad and parsed using the USGS metadata compiler program (MP) to locate errors and omissions (USGS 2004). After all errors and omissions were corrected, MP was used to generate final TXT, HTML, and XML versions of each metadata record which are stored in the air photo archive. Key information for the Hopewell Furnace National Historic Site mosaic is summarized in Table A1.

Figure A1. Ground control points (n=12) used to calculate horizontal positional accuracy of the Hopewell Furnace National Historic Site mosaic.

Table A1. Summary of key information for Hopewell Furnace National Historic Site mosaic.

Title of metadata record:	Hopewell Furnace NHS Color Infrared Orthorectified Photomosaic (hofu_spring.img and hofu_spring.sid)
Publication date of mosaic (from metadata):	September 30, 2002
Date aerial photography was acquired:	April 4, 2002 (leaf-off)
Vendor that provided aerial photography:	Kucera International
Scale of photography:	1:6,000
Type of photography:	Color infrared, stereo pairs
Number of air photos delivered:	25
Archive location of air photos, airborne GPS/IMU files, camera calibration certificate, and hardcopy flight reports:	North Carolina State University, Center for Earth Observation
Scanning specifications:	600 dpi, 24-bit color depth
Horizontal positional accuracy of mosaic:	1.27 meters, meets Class 1 National Map Accuracy Standard
Number of ground control points upon which estimated accuracy is based:	12
Method of calculating positional accuracy:	Euclidean distance
Archive location of mosaic and metadata:	North Carolina State University, Center for Earth Observation
Format(s) of archived mosaic:	.img (uncompressed); MrSID (20:1 compression)

Literature Cited

Environmental Systems Research Institute (ESRI), National Center for Geographic Information and Analysis (NCGIA), and The Nature Conservancy (TNC). November 1994. Accuracy assessment procedures, NBS/NPS Vegetation Mapping Program. Retrieved October 2001 from http://biology.usgs.gov/npsveg/aa/aa.html.

Federal Geographic Data Committee. 1998a. Content standard for digital geospatial metadata (FGDC-STD-001-1998). Retrieved October 2001 from http://www.fgdc.gov/metadata/contstan.html

Federal Geographic Data Committee (FGDC). 1998b. Geospatial positioning accuracy standards, Part 3: National Standard for Spatial Data Accuracy. (FGDC-STD-007.3-1998). Retrieved October 2001 from http://www.fgdc.gov/standards/status/sub1_3.html

United States Geological Survey (USGS). 2004. Tools for creation of formal metadata, a compiler for formal metadata. Retrieved June 2004 from http://geology.usgs.gov/tools/metadata/tools/doc/mp.html

Appendix B. Vegetation classification plot sampling and accuracy assessment field forms.

3: Quantitative Community Characterization Draft: Spring, 1997

National Park Service Vegetation Sampling

A. Identifiers (general EOR information)

Sci. name: 1.SNAME:_____ 2.GNAME:_____ 3.Site name:
4.Survey site name:_____ 5.Quad name(s):_____ 6.Quad code(s):
7.County name(s):_____ 8.County code(s):_____ 9.Town (LOCALJURIS):
10.Lat:_ _ _ _ _ _ N 11.Long: 0 _ _ _ _ _ _ W OR UTM Zone _____ Datum_____
Easting: 0 _ _ _, _ _ _ Northing: _, _ _ _, _ _ _
12.Directions:
13.Sourcecode:_____ 14.Survey date:_____.__.
15.Last obs:_____.__.__ 16.First obs:_____.__.__ 17.State:
18.Surveyors:_____ Image
Annotation:_____

B. Environmental Description

23.Topographic sketch

Elevation:_____
Slope aspect:_____
Parent material:

32.Stoniness:
__ Stone free <0.1%
__ Moderately stony 0.1-1%
__ Stony 3-15%
__ Very stony 15-50%
__ Exceedingly stony 50-90%
__ Stone piles >90%

Topographic position:
___ Interfluve ___ Back slope
___ High Slope ___ Step in slope
___ High level ___ Low slope
___ Midslope ___ Toe slope
___ Low level ___ Channel wall
___ Basin floor ___ Swale
___ Channel bed ___ Other (_____)

33. Soil drainage:
___ Rapidly drained ___ Somewhat poorly drained
___ Well drained ___ Poorly Drained
___ Moderately well drained ___ Very poorly drained

34.Average texture:
___ sand ___ clay loam
___ sandy loam ___ clay
___ loam ___ peat
___ silt loam ___ muck
___ other :_____

27.Soil profile description: note depth, texture, and color of each horizon. Note significant changes such as depth to mottling, depth to water table, root penetration depth (SOILCOM)

28.Organic horizon depth:
29.Organic horizon type:

30.Average pH of mineral soil:

31.Hydrologic regime:
___Permanently flooded ___Saturated
___Intermittently exposed ___Temporarily flooded
___ Semi-permanently flooded ___Intermittently flooded
flooded ___ Artificially flooded
___ Seasonally flooded ___ Never flooded

35.Unvegetated surface:
___% Bedrock ___% Wood (> 1 cm)
___% Large rocks (cobbles, boulders > 10 cm) ___ % Litter, duff
___% Small rocks (gravel, 0.2-10 cm) ___% Water
___% Sand (0.1-2 mm) ___ % Other:
___% Bare soil

36.Environmental Comments: Note homogeneity of vegetation, erosion / sedimentation, inundation, etc.

37.Plot representativeness:

C. Vegetation

38. System: _____Terrestrial _____ Palustrine _____ Estuarine 39.Plot number:_____ 40.Plot dimensions:

41.Leaf Type	42. Leaf Phenology	43. Physiognomic Type	
___ Broad-leaf	___ Deciduous	___ Forest	___ Woodland
___ Semi-broad-leaf	___ Semi-deciduous	___ Sparse Woodland	___ Scrub Thicket
___ Semi-needle-leaf	___ Semi-evergreen	___ Shrubland	___ Sparse Woodland
___ Needle-leaf	___ Evergreen	___ Dwarf Shrubland	___ Dwarf Scrub Thicket
___ Broad-leaf herbaceous	___ Perennial	___ Sparse Dwarf Shrubland	___ Herbaceous
___ Graminoid	___ Annual	___ Non-Vascular	___ Sparsely Vegetated
___ Pteridophyte			

44	height	% cover
T1 Emergent tree		
T2 Tree canopy		
T3 Tree sub-canopy		
S1 Tall shrub		
S2 Short shrub		
H Herbaceous		
N Non-vascular		
E Epiphyte		
V Vine / liana		

R = 1 or few (+) = occasional 1 = <5% 2- = 5-12% 2+ = 13-25% 3 = 26-50% 4 = 51-75% 5 = 76+%

45.Species / percent cover: starting with uppermost stratum, list all species and % cover for each in the stratum. For forests and woodlands, list on a separate line below each tree species the DBH of all trees above 10 cm diameter. Separate the measurements with a comma and note whether in cm or inches.

Accuracy Assessment Form
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

_____

_____

_____

_____

_____

Instructions for Accuracy Assessment

The basic document for accuracy assessment is "Accuracy Assessment Procedures", developed by the Program in 1994. The document can be downloaded from the Program web site at http://biology.usgs.gov/npsveg. This accuracy assessment (AA) form is the result of an additional 4 years of field experience. The purpose of this form is to generate concise data to document the accuracy assessment procedure that occurred in the field and to compare it to the mapped data.

All navigation must occur with either a Y-code GPS receiver (e.g. Rockwell PLGR) or in real time differential mode if using other types of receivers. This unit allows the user to navigate to sites within a few meters of their actual locations. The AA sites will be selected using randomly located samples stratified according to the associations. Before beginning each morning, make sure the datum is set to NAD83, and that the projection system is UTM, with the proper zone. A compass is needed to estimate aspect.

The materials you should have before you begin are a 1) plots of the DOQQ's showing the polygon boundaries, but no information on polygon attributes, and the location of the AA sites with numbers, 2) AA site coordinates loaded into your GPS receiver, 3) the field key, and 4) association descriptions.

Once you have navigated to an accuracy assessment site, and the FOM (Figure of Merit) is at 1, if using a PLGR, observe the vegetation within a 50 meter radius of the site. To gauge how far 50 meters is, it is helpful to have the navigator pace 50 meters in one direction. Document what the vegetation community is at the site, and if there are more than one community present within a 50 meter radius, document those as well under Veg Assoc 2 & 3.

Specific Instructions:

1. Plot Number - self explanatory
2. Park Code - the four character code for the park (e.g. Voyageurs is VOYA, Scotts Bluff is SCBL)
3. Date - self explanatory
4. Observor(s) - self explanatory
5. Datum - the reference system for the projection, should be NAD83 (NAR on the PLGR)
6. Accuracy - the distance in meters the GPS receiver displays, if using a PLGR
7. UTM Coordinates - easting and northing in meters
8. UTM Zone - UTM zones in continental US range between 10 (126 ^{0} W longitude on the Pacific Coast) and 19 (66 ^{o} W longitude on the Atlantic Coast)
9. Offset from Site - if you are unable to navigate directly to a site due to terrain problems (e.g., rivers, canyons), record the distance from the site displayed on your GPS receiver, record 0 if there is no offset
10. Topographic Description - where you are on the terrain; on the top of a hill, in a small valley, midslope on a south facing slope, etc.
11. Elevation - above sea level in meters
12. Aspect - using a compass estimate the aspect of the whole site, record in degrees of azimuth (0-360)
13. Veg Assoc at Site - use the field key determine the association directly on the AA site
14. Veg Assoc 2 within 50 m of Site - if a second vegetation association is found within 50 meters of the site, record that association.
15. Veg Assoc 3 within 50 m of Site - if a third vegetation association is found within 50 meters of the site, record that association
16. Major Species Present (by strata) - record the major and indicator species present

1. Canopy Closure of Top Layer - estimate canopy closure of top stratum, eliminating the contribution from lower strata.
2. Rationale for Classification - record the logical procedure you used to determine the vegetation association based on indicator species, major species, structure, etc.
3. Comments - all relevant information that does not fit into the fields above. Note such things as multiple associations near the site, indications of artificial influences on the vegetation, such as grazing, logging, animal presence or use, influences of elevation, aspect, water tables, etc

Appendix E. List of vascular plants identified in vegetation classification and accuracy assessment plots (nomenclature follows Kartez 1994).

Appendix E. List of vascular plants identified in vegetation classification and accuracy assessment plots.

Family	Scientific Name	Common Name
Aceraceae	*Acer rubrum* L.	red maple
Alismataceae	*Sagittaria latifolia* Willd.	broadleaf arrowhead
Anacardiaceae	*Rhus typhina* L.	staghorn sumac
Anacardiaceae	*Toxicodendron radicans* (L.) Kuntze	eastern poison ivy
Anacardiaceae	*Toxicodendron vernix* (L.) Kuntze	poison sumac
Apiaceae	*Sanicula smallii* Bickn.	Small's black snakeroot
Aquifoliaceae	*Ilex verticillata* (L.) Gray	common winterberry
Araceae	*Arisaema triphyllum* (L.) Schott	Jack-in-the-pulpit
Araceae	*Symplocarpus foetidus* (L.) Salisb. ex Nutt.	skunk cabbage
Araliaceae	*Aralia nudicaulis* L.	wild sarsaparilla
Aspleniaceae	*Asplenium platyneuron* (L.) B.S.P.	ebony spleenwort
Asteraceae	*Achillea millefolium* L.	common yarrow
Asteraceae	*Ambrosia artemisiifolia* L.	annual ragweed
Asteraceae	*Aster divaricatus* (Nutt.) Torr. & Gray	woodland aster
Asteraceae	*Aster* L.	aster
Asteraceae	*Chrysanthemum parthenium* (L.) Bernh.	feverfew
Asteraceae	*Cirsium* P. Mill.	thistle
Asteraceae	*Erigeron philadelphicus* L.	Philadelphia fleabane
Asteraceae	*Eupatorium rugosum* Houtt.	white snakeroot
Asteraceae	*Solidago* L.	goldenrod
Asteraceae	*Taraxacum officinale* G.H. Weber ex Wiggers	common dandelion
Asteraceae	*Vernonia noveboracensis* (L.) Michx.	New York ironweed
Balsaminaceae	*Impatiens capensis* Meerb.	jewelweed
Berberidaceae	*Berberis thunbergii* L.	Japanese barberry
Betulaceae	*Alnus serrulata (Ait.)* Willd.	hazel alder
Betulaceae	*Betula alleghaniensis* Britt.	yellow birch
Betulaceae	*Betula lenta* L.	sweet birch
Betulaceae	*Carpinus caroliniana* Walt.	American hornbeam
Betulaceae	*Ostrya virginiana* (P. Mill.) K. Koch	eastern hophornbeam
Boraginaceae	*Hackelia virginiana* (L.) I.M. Johnston	beggarslice
Brassicaceae	*Alliaria officinalis* Andrz. ex Bieb.	garlic mustard
Brassicaceae	*Barbarea vulgaris* Ait. f.	garden yellowrocket
Caprifoliaceae	*Lonicera japonica* Thunb.	Japanese honeysuckle
Caprifoliaceae	*Lonicera morrowii* Gray	Morrow's honeysuckle
Caprifoliaceae	*Lonicera tatarica* L.	Tatarian honeysuckle
Caprifoliaceae	*Viburnum acerifolium* L.	maple-leaved viburnum
Caprifoliaceae	*Viburnum dentatum* L.	southern arrowwood
Caprifoliaceae	*Viburnum lentago* L.	nannyberry
Caprifoliaceae	*Viburnum prunifolium* L.	Blackhaw

Appendix E. List of vascular plant species identified in vegetation classification plots (continued).

Family	Scientific Name	Common Name
Caprifoliaceae	*Viburnum recognitum* Fern.	northern arrowwood
Celastraceae	*Celastrus orbiculatus* Thunb.	Asian bittersweet
Clusiaceae	*Hypericum boreale* (Britt.) Bickn.	northern St. Johnswort
Convolvulaceae	*Convolvulus* L.	bindweed
Cornaceae	*Cornus florida* L.	flowering dogwood
Crassulaceae	*Penthorum sedoides* L.	ditch stonecrop
Cucurbitaceae	*Sicyos angulatus* L.	oneseed burr cucumber
Cupressaceae	*Juniperus virginiana* L.	eastern red cedar
Cuscutaceae	*Cuscuta* L.	dodder
Cyperaceae	*Carex bromoides* Schkuhr ex Willd.	brome sedge
Cyperaceae	*Carex comosa* Boott	longhair sedge
Cyperaceae	*Carex debilis* Michx.	white edge sedge
Cyperaceae	*Carex* L.	sedge
Cyperaceae	*Carex ovalis* Goodenough	sedge
Cyperaceae	*Carex pensylvanica* Lam.	Pennsylvania sedge
Cyperaceae	*Carex stricta* Lam.	uptight sedge
Cyperaceae	*Carex vulpinoidea* Michx.	fox sedge
Cyperaceae	*Scirpus atrovirens* Willd.	green bulrush
Dennstaedtiaceae	*Dennstaedtia punctilobula* (Michx.) T. Moore	eastern hay-scented fern
Dennstaedtiaceae	*Pteridium aquilinum* (L.) Kuhn	western brackenfern
Dioscoreaceae	*Dioscorea villosa* L.	wild yam
Dryopteridaceae	*Dryopteris carthusiana* (Vill.) H.P. Fuchs	spinulose woodfern
Dryopteridaceae	*Dryopteris cristata* (L.) Gray	crested woodfern
Dryopteridaceae	*Dryopteris marginalis* (L.) Gray	marginal woodfern
Dryopteridaceae	*Onoclea sensibilis* L.	sensitive fern
Dryopteridaceae	*Polystichum acrostichoides* (Michx.) Schott	Christmas fern
Elaeagnaceae	*Elaeagnus umbellata* Thunb.	autumn olive
Ericaceae	*Gaylussacia baccata* (Wangenh.) K. Koch	black huckleberry
Ericaceae	*Gaylussacia frondosa* (L.) Torr. & Gray ex Torr.	blue huckleberry
Ericaceae	*Kalmia latifolia* L.	mountain laurel
Ericaceae	*Lyonia ligustrina* (L.) DC.	maleberry
Ericaceae	*Rhododendron periclymenoides* (Michx.) Shinners	pink azalea
Ericaceae	*Rhododendron viscosum* (L.) Torr.	swamp azalea
Ericaceae	*Vaccinium angustifolium* Ait.	lowbush blueberry
Ericaceae	*Vaccinium corymbosum* L.	highbush blueberry
Ericaceae	*Vaccinium pallidum* Ait.	Blue Ridge blueberry
Fabaceae	*Amphicarpaea bracteata* (L.) Fern.	American hogpeanut
Fabaceae	*Desmodium* Desv.	ticktrefoil
Fabaceae	*Desmodium nudiflorum* (L.) DC.	nakedflower ticktrefoil

Appendix E. List of vascular plants identified in vegetation classification and accuracy assessment plots (continued).

Family	Scientific Name	Common Name
Fagaceae	*Castanea dentata* (Marsh.) Borkh.	American chestnut
Fagaceae	*Fagus grandifolia* Ehrh.	American beech
Fagaceae	*Quercus alba* L.	white oak
Fagaceae	*Quercus bicolor* Willd.	swamp white oak
Fagaceae	*Quercus coccinea* Muenchh.	scarlet oak
Fagaceae	*Quercus palustris* Muenchh.	pin oak
Fagaceae	*Quercus prinus* L.	chestnut oak
Fagaceae	*Quercus rubra* L.	northern red oak
Fagaceae	*Quercus velutina* Lam.	black oak
Geraniaceae	*Geranium maculatum* L.	spotted geranium
Hamamelidaceae	*Hamamelis virginiana* L.	American witchhazel
Juglandaceae	*Carya cordiformis* (Wangenh.) K. Koch	bitternut hickory
Juglandaceae	*Carya glabra* (P. Mill.) Sweet	pignut hickory
Juglandaceae	*Carya ovalis* (Wangenh.) Sarg.	red hickory
Juglandaceae	*Carya ovata* (P. Mill.) K. Koch	shagbark hickory
Juglandaceae	*Juglans nigra* L.	black walnut
Juncaceae	*Juncus effusus* L.	common rush
Juncaceae	*Juncus* L.	rush
Lamiaceae	*Prunella vulgaris* L.	common selfheal
Lamiaceae	*Scutellaria* L.	skullcap
Lamiaceae	*Scutellaria lateriflora* L.	blue skullcap
Lauraceae	*Lindera benzoin* (L.) Blume	northern spicebush
Lauraceae	*Sassafras albidum* (Nutt.) Nees	sassafras
Lemnaceae	*Lemna* L.	duckweed
Liliaceae	*Maianthemum canadense* Desf.	Canada beadruby
Liliaceae	*Medeola virginiana* L.	Indian cucumberroot
Liliaceae	*Smilacina racemosa* (L.) Desf.	false Solomon’s seal
Liliaceae	*Uvularia perfoliata* L.	perfoliate bellwort
Magnoliaceae	*Liriodendron tulipifera* L.	tulip poplar
Monotropaceae	*Monotropa uniflora* L.	Indianpipe
Nyssaceae	*Nyssa sylvatica* Marsh.	black gum
Oleaceae	*Fraxinus americana* L.	white ash
Oleaceae	*Fraxinus nigra* Marsh.	black ash
Oleaceae	*Fraxinus pennsylvanica* Marsh.	green ash
Onagraceae	*Circaea lutetiana* L.	broadleaf enchanter's nightshade
Onagraceae	*Circaea quadrisulcata var. canadensis* (L.) Hara	enchanter’s nightshade
Onagraceae	*Epilobium* L.	willowweed
Onagraceae	*Ludwigia palustris* (L.) Ell.	marsh seedbox

Appendix E. List of vascular plants identified in vegetation classification and accuracy assessment plots (continued).

Family	Scientific Name	Common Name
Ophioglossaceae	*Botrychium dissectum* Spreng.	cutleaf grapefern
Orchidaceae	*Goodyera pubescens* (Willd.) R. Br. ex Ait. f.	downy rattlesnake plantain
Osmundaceae	*Osmunda cinnamomea* L.	cinnamon fern
Osmundaceae	*Osmunda regalis* L.	royal fern
Oxalidaceae	*Oxalis stricta* L.	common yellow oxalis
Platanaceae	*Platanus occidentalis* L.	American sycamore
Poaceae	*Anthoxanthum odoratum* L.	sweet vernalgrass
Poaceae	*Cinna* L.	woodreed
Poaceae	*Cinna latifolia* (Trev. ex Goepp.) Griseb.	drooping woodreed
Poaceae	*Cinna arundinacea* L.	sweet woodreed
Poaceae	*Dactylis glomerata* L.	orchardgrass
Poaceae	*Elymus hystrix* L.	eastern bottlebrush grass
Poaceae	*Glyceria grandis* S. Wats.	American mannagrass
Poaceae	*Glyceria* R. Br.	mannagrass
Poaceae	*Leersia oryzoides* (L.) Sw.	rice cutgrass
Poaceae	*Leersia virginica* Willd.	whitegrass
Poaceae	*Microstegium vimineum* (Trin.) A. Camus	Nepalese browntop
Poaceae	*Panicum acuminatum* Sw.	panic grass
Poaceae	*Panicum anceps* Michx.	beaked panicum
Poaceae	*Panicum clandestinum* L.	deer-tongue grass
Poaceae	*Panicum* L.	panicum
Poaceae	*Poa compressa* L.	Canada bluegrass
Poaceae	*Poa* L.	bluegrass
Poaceae	*Poa palustris* L.	fowl bluegrass
Polygonaceae	*Polygonum arifolium* L.	halberdleaf tearthumb
Polygonaceae	*Polygonum cespitosum* Blume	oriental ladysthumb
Polygonaceae	*Polygonum hydropiper* L.	marshpepper knotweed
Polygonaceae	*Polygonum* L.	knotweed
Polygonaceae	*Polygonum sagittatum* L.	arrowleaf tearthumb
Polygonaceae	*Polygonum scandens* L.	climbing false buckwheat
Polygonaceae	*Polygonum virginianum* L.	jumpseed
Polypodiaceae	*Polypodium virginianum* L.	rock polypody
Primulaceae	*Trientalis borealis* Raf.	American starflower
Pyrolaceae	*Chimaphila maculata* (L.) Pursh	striped prince's pine
Pyrolaceae	*Chimaphila umbellata* (L.) W. Bart.	pipsissewa
Ranunculaceae	*Clematis virginiana* L.	devil's darning needles
Ranunculaceae	*Ranunculus hispidus* Michx.	bristly buttercup
Ranunculaceae	*Ranunculus* L.	buttercup
Rosaceae	*Agrimonia* L.	agrimony
Rosaceae	*Agrimonia rostellata* Wallr.	beaked agrimony
Rosaceae	*Amelanchier arborea* (Michx. f.) Fern.	common serviceberry

Appendix E. List of vascular plants identified in vegetation classification and accuracy assessment plots (continued).

Family	Scientific Name	Common Name
Rosaceae	*Amelanchier* Medik.	serviceberry
Rosaceae	*Crataegus* L.	hawthorn
Rosaceae	*Fragaria virginiana* Duchesne	Virginia strawberry
Rosaceae	*Geum* L.	avens
Rosaceae	*Potentilla* L.	cinquefoil
Rosaceae	*Prunus* L.	prunus
Rosaceae	*Prunus serotina* Ehrh.	black cherry
Rosaceae	*Prunus virginiana* L.	common chokecherry
Rosaceae	*Rosa multiflora* Thunb. ex Murr.	multiflora rose
Rosaceae	*Rosa palustris* Marsh.	swamp rose
Rosaceae	*Rubus allegheniensis* Porter	Allegheny blackberry
Rosaceae	*Rubus hispidus* L.	bristly dewberry
Rosaceae	*Rubus idaeus* L.	American red raspberry
Rosaceae	*Rubus philadelphicus* Blanch.	Philadelphia blackberry
Rosaceae	*Rubus phoenicolasius* Maxim.	wine raspberry
Rosaceae	*Spiraea* L.	spirea
Rubiaceae	*Cephalanthus occidentalis* L.	common buttonbush
Rubiaceae	*Galium aparine* L.	stickywilly
Rubiaceae	*Galium asperulum* (Gray) Rydb.	bedstraw
Rubiaceae	*Galium asprellum* Michx.	rough bedstraw
Rubiaceae	*Galium circaezans* Michx.	licorice bedstraw
Rubiaceae	*Galium concinnum* Torr. & Gray	shining bedstraw
Rubiaceae	*Galium palustre* L.	common marsh bedstraw
Rubiaceae	*Galium triflorum* Michx.	fragrant bedstraw
Rubiaceae	*Mitchella repens* L.	partridgeberry
Salicaceae	*Populus grandidentata* Michx.	big-toothed aspen
Saxifragaceae	*Chrysosplenium americanum* Schwein. ex Hook.	American golden saxifrage
Scrophulariaceae	*Melampyrum lineare* Desr.	narrowleaf cowwheat
Scrophulariaceae	*Mimulus ringens* L.	ringen monkeyflower
Scrophulariaceae	*Linaria vulgaris* P. Mill.	butter and eggs
Simaroubaceae	*Ailanthus altissima* (P. Mill.) Swingle	tree of heaven
Smilacaceae	*Smilax glauca* Walt.	cat greenbrier
Smilacaceae	*Smilax rotundifolia* L.	roundleaf greenbrier
Solanaceae	*Solanum carolinense* L.	Carolina horsenettle
Thelypteridaceae	*Thelypteris noveboracensis* (L.) Nieuwl.	New York fern
Thelypteridaceae	*Thelypteris palustris* Schott	eastern marsh fern
Thelypteridaceae	*Thelypteris phegopteris* (L.) Slosson	long beach fern
Typhaceae	*Typha latifolia* L.	broadleaf cattail

Appendix E. List of vascular plants identified in vegetation classification and accuracy assessment plots (continued).

Family	Scientific Name	Common Name
Ulmaceae	*Celtis occidentalis* L.	common hackberry
Ulmaceae	*Ulmus americana* L.	American elm
Urticaceae	*Boehmeria cylindrica* (L.) Sw.	smallspike false nettle
Urticaceae	*Laportea canadensis* (L.) Weddell	Canadian woodnettle
Urticaceae	*Pilea* Lindl.	clearweed
Urticaceae	*Pilea pumila* (L.) Gray	Canadian clearweed
Verbenaceae	*Phryma leptostachya* L.	American lopseed
Verbenaceae	*Verbena hastata* L.	swamp verbena
Violaceae	*Viola* L.	violet
Violaceae	*Viola sororia* Willd.	common blue violet
Vitaceae	*Parthenocissus quinquefolia* (L.) Planch.	Virginia creeper
Vitaceae	*Vitis aestivalis* Michx.	summer grape
Vitaceae	*Vitis labrusca* L.	fox grape
Vitaceae	*Vitis riparia* Michx.	riverbank grape
Vitaceae	*Vitis vulpina* L.	frost grape

As the nation's primary conservation agency, the Department of the Interior has responsibility for most of our nationally owned public land and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-96 March 2005 (revised October 2005)

National Park Service
U.S. Department of the Interior

Northeast Region
Natural Resource Stewardship and Science
200 Chestnut Street
Philadelphia, Pennsylvania 19106-2878

http://www.nps.gov/nero/science/

EXPERIENCE YOUR AMERICA ™