National Park Service
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Natural Resource Stewardship and Science

National Park Service
Vegetation Mapping Inventory Program

Great Smoky Mountains National Park
Vegetation Mapping Project

Natural Resource Report NPS/GRSM/NRR—2021/2285

ON THIS PAGE
Photographs collected in Great Smoky Mountains National Park, North Carolina and Tennessee. From upper left clockwise to center: The view into the Park from Brushy Mountain, Red Spruce - Fraser Fir Forest (Deciduous Shrub Type) (CEGL007131) along the Forney Ridge Trail, foamflower (*Tiarella cordifolia*) along the Thomas Divide Trail, the endemic red-cheeked salamander (*Plethodon jordani*), Ramsey Cascades, American black bear (*Ursus americanus*) cub, and old growth blackgum (*Nyssa sylvatica*) along the McKee Branch Trail.
Photographs by Andrew Strassman (U.S. Geological Survey).

ON THE COVER
Looking south into the Deep Creek Valley of Great Smoky Mountains National Park from State Highway 441.
Photograph by Andrew Strassman (U.S. Geological Survey)

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Contents

Contents (continued)

Contents (continued)

Figures

Page

Tables

Page

Appendixes

Executive Summary

The National Park Service (NPS) Vegetation Mapping Inventory (VMI) Program is an effort to classify, describe, and map existing vegetation communities in national park units throughout the United States. The NPS VMI Program is managed by the NPS Natural Resource Stewardship and Science Inventory and Monitoring Program and provides baseline vegetation information to natural resource managers, researchers, and ecologists. The U.S. Geological Survey Upper Midwest Environmental Sciences Center, NatureServe, and NPS Great Smoky Mountains National Park (GRSM, also referred to as the "Park") have completed vegetation classification and mapping of GRSM, including the Foothills Parkway, for the NPS VMI Program.

Mappers, ecologists, and botanists collaborated to affirm vegetation types of GRSM and to determine how best to map the vegetation types by using aerial imagery. A vegetation classification developed in 2003 by NatureServe and the NPS served as a foundation to further classify and map the vegetation types of the Park. Data from an additional 10 vegetation plots supported vegetation types either rare or not documented in the 2003 classification. Data from 203 verification sites were collected to test the field key to vegetation types and the application of vegetation types to a sample set of map polygons. Furthermore, data from 972 accuracy assessment (AA) sites were collected (of which 966 were used to test accuracy of the vegetation map layer). This GRSM vegetation mapping project identified 112 vegetation types consisting of 105 association types in the U.S. National Vegetation Classification (USNVC), 2 "park-special" types, 1 "map-special" type, and 4 cultural types in the USNVC.

To map the vegetation and land cover of GRSM, 52 map classes were developed. Of these 52 map classes, 46 represent natural (including ruderal) vegetation types, most of which types are recognized in the USNVC. For the remaining 6 of the 52 map classes, 4 represent USNVC cultural types for agricultural and developed areas, and 2 represent non-USNVC types for nonvegetated open water and nonvegetated rock. Features were interpreted from viewing four-band digital aerial imagery using digital onscreen three-dimensional stereoscopic workflow systems in geographic information systems; digital aerial imagery was collected during September 23–October 30, 2015. The interpreted data were digitally and spatially referenced, thus making the spatial-database layers usable in a geographic information system. Polygon units were mapped to either a 0.5- or 0.25- hectare (ha) minimum mapping unit, depending on vegetation type.

A geodatabase containing several feature-class layers and tables provides the locations and data of USNVC vegetation types (vegetation map layer), vegetation plots, verification sites, AA sites, project boundary extent, and aerial image centers and flight lines.

Covering 210,875 ha, the feature-class layer and related tables for the vegetation map layer provide 34,084 polygons of detailed attribute data when special modifiers are not considered (average polygon size of 6.2 ha) and 36,589 polygons of detailed attribute data when special modifiers are considered (average polygon size of 5.8 ha). Each map polygon is assigned a map-class code and name and, when applicable, are linked to USNVC classification tables within the geodatabase. The vegetation map extent includes the administrative boundary for GRSM and the Foothills Parkway.

A summary report, generated from the vegetation map layer, concludes that the 46 map classes representing natural (including ruderal) vegetation types apply to 99.2% of polygons (33,797 polygons; average size of 6.2 ha) and cover 98.6% of the Park (207,971.4 ha). Further broken down, map classes representing natural vegetation types indicate that the Park is 97.7% forest and woodland (205,882.5 ha), 0.6% shrubland (1,174.6 ha), and 0.4% herbaceous (914.3 ha). Map classes representing cultural vegetation types apply to 0.8% of polygons (259 polygons; average size of 4.9 ha) and cover 0.6% of the Park (1,277.4 ha). Map classes representing nonvegetation open and flowing water and unvegetated rock apply to 0.08% of polygons (28 polygons; average size of 58.1 ha) and cover 0.8% of the Park (1,625.9 ha).

A thematic AA study was completed of map classes representing the natural (including ruderal) vegetation types of the Park. Initial AA results were discussed with NPS staff from the Park. Following input from NPS staff on how to handle map classes that fell below accuracy standards, adjustments were made to the vegetation map layer. Final results indicate an overall accuracy of 80.64% (kappa index of 79.96% for chance agreements) based on data from 966 of the 972 AA sites. Most individual map-class themes exceed the NPS VMI Program standard of 80% with a 90% confidence interval.

The GRSM vegetation mapping project delivers many geospatial and vegetation data products, including an in-depth project report discussing methods and results, which includes map classification and map-class descriptions. This suite of products also includes descriptions and a field key to vegetation types; a database of vegetation plots, verification sites, and AA sites; digital images of field sites; field data sheets; digital aerial imagery; hardcopy and digital maps; a geodatabase of vegetation and land cover (map layer), field sites (vegetation plots, verification sites, and AA sites), aerial imagery index, project boundary, and metadata; and a contingency table listing AA results. Geospatial products are projected in the Universal Transverse Mercator, Zone 17 North, by using the North American Datum of 1983. Information on the NPS VMI Program and completed mapping projects are on the internet at https://www.nps.gov/im/vegetation-inventory.htm.

Acknowledgments

The success of this vegetation mapping project was dependent on the collaborative efforts of several individuals from various organizations. The dedicated people who worked on this project collectively have a wide array of knowledge, skill, and expertise; these people were essential in moving the National Park Service (NPS) Great Smoky Mountains National Park (GRSM) vegetation mapping project to its completion. The authors of this report wish to acknowledge those individuals who were vital in making this vegetation mapping project a success.

Funding for this project was provided by the NPS Vegetation Mapping Inventory (VMI) Program with additional funding by the U.S. Geological Survey (USGS). The authors respectfully thank NPS VMI Program staff for entrusting us with this project. The authors also thank the staff members associated with GRSM for dutifully supporting this project, in particular Tom Remaley, Troy Evans, and Rob Klein; their diligence to host and engage in the series of meetings, training sessions, and field efforts is much appreciated. Furthermore, the authors thank GRSM support staff for their contribution to the accuracy assessment of the vegetation map, including Josh Albritton and Ian Sabo for their field data collection, and Kendra Straub and Tom Colson for their database management. Additional thanks go to Michael Schafale of the North Carolina Natural Heritage Program for assistance with specific classification matters, and to Todd Crabtree and Roger McCoy of the Tennessee Natural Heritage Inventory Program for assistance with some accuracy assessment field data collection.

The authors also acknowledge our colleagues from within our own offices—the USGS Upper Midwest Environmental Sciences Center (UMESC) and NatureServe. Of UMESC, the authors acknowledge Larry Robinson for managing the collection of digital aerial imagery, Janis Ruhser for geoprocessing the aerial imagery, and Erin Hoy for participating on the UMESC mapping team. Of NatureServe, the authors acknowledge Don Faber-Langendoen for his ecological classification expertise and Kristin Snow for her responsive and thorough classification management. The authors further thank the assistance others have provided to the project, including Eric Lund of the Minnesota Department of Natural Resources for contributing to the accuracy assessment analysis and making product consistency reviews, and Tennessee Natural Heritage Program for assisting in some field data collection for the accuracy assessment effort.

All photograph images in this report are by authors of or contributors to this report unless otherwise specified.

Introduction and Project Overview

This report describes the Great Smoky Mountains National Park (GRSM) vegetation mapping project for the National Park Service (NPS) Vegetation Mapping Inventory (VMI) Program. This "Introduction and Project Overview" section provides a general description of the vegetation mapping project without an in-depth review of the methods and results. The report then begins an in-depth description of the methods and results for the three main components of the project to provide the details necessary to replicate this project. These three main components are vegetation classification, vegetation mapping, and accuracy assessment (AA). Appendixes are included and referenced in the report to provide further detail. Because of the length of this report, acronyms are reestablished for each main section and appendix. Throughout this report, GRSM also is referred to as the "Park."

Great Smoky Mountains National Park[1]

The GRSM was officially established as a National Park in 1934, with purpose to "preserves a vast expanse of the southern Appalachian Mountains ecosystem including its scenic beauty, extraordinary diversity of natural resources, and rich human history, and provides opportunities for the enjoyment and inspiration of present and future generations." The Park, including the Foothills Parkway, covers nearly 211,000 hectares (ha) in the Southern Appalachian Mountains of North Carolina and Tennessee (Figure 1) with elevations ranging from 260 to 2,025 meters above mean sea level (msl). Nearly 1,300 kilometers of trails are maintained throughout GRSM, including a part of the Appalachian Trail. The Park is home to one of the world's highest diversity of plants, animals, and invertebrates within the temperate climate.

National Park Service Vegetation Mapping Inventory Program

The NPS VMI Program classifies, describes, and maps existing vegetation of national park units with a significant natural resource. Managed by the NPS Natural Resource Stewardship and Science (NRSS) Inventory and Monitoring Program (IMP), the NPS VMI Program provides to the NRSS IMP baseline vegetation information needed to manage ecosystem integrity for NPS units. Vegetation layers and associated information support a variety of resource assessment, park management, and planning needs. The layers and information also provide structure for framing and answering critical scientific questions about vegetation communities and their relation to environmental processes across the landscape.

Program Procedures and Standards

Program scientists developed procedures for classifying and mapping vegetation and for completing a mapping AA (The Nature Conservancy and Environmental Systems Research Institute 1994a, 1994b; The Nature Conservancy et al. 1994; NatureServe 2004; Lea and Curtis 2010). Ecology and

[1]Information within this section was partly compiled from the web site for GRSM at https://www.nps.gov/grsm.

mapping teams collaborated to share knowledge and data and to resolve issues regarding classification and mapping procedures.

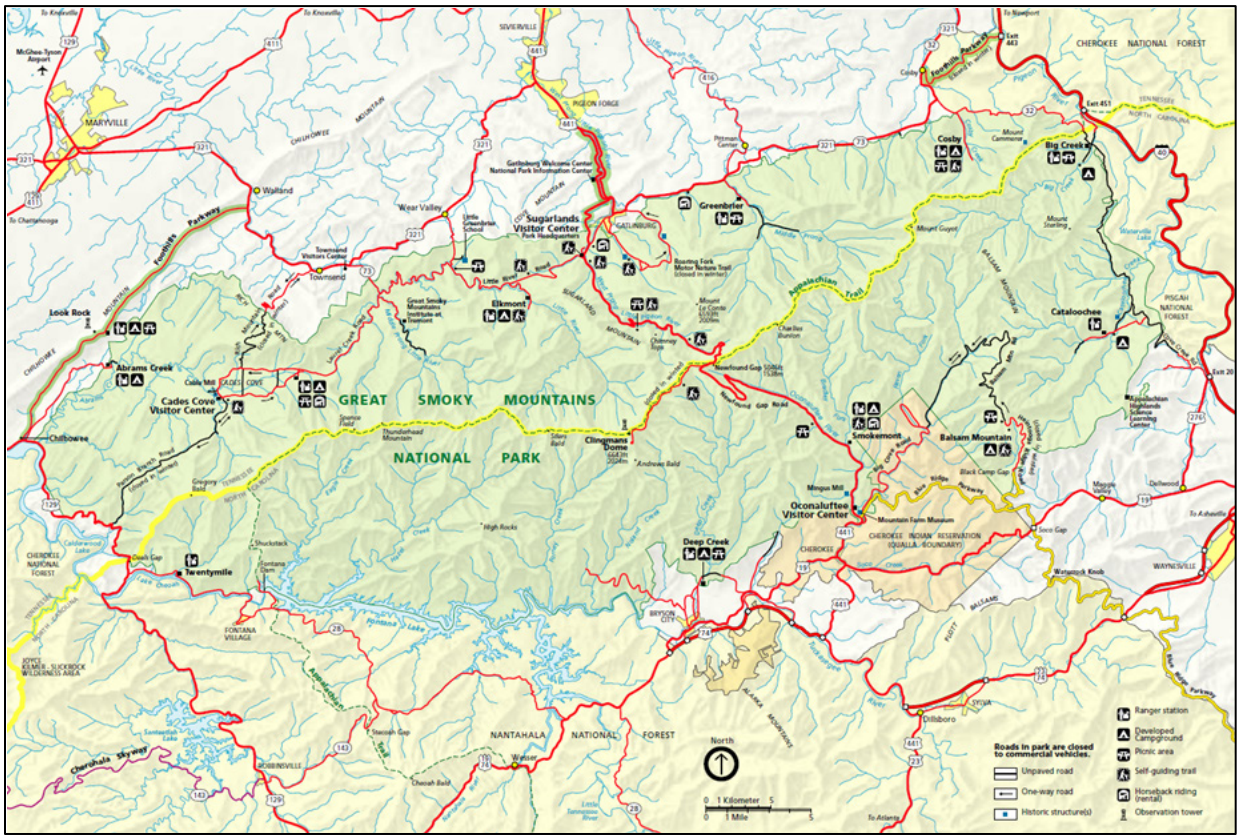

Figure 1. Great Smoky Mountains National Park, North Carolina and Tennessee (courtesy of National Park Service).

Products of the NPS VMI Program meet Federal Geographic Data Committee standards for vegetation classification and metadata and national standards for spatial accuracy and data transfer. These standards include the following:

- National Vegetation Classification Standard (NVCS) (Federal Geographic Data Committee 2008),
- Content Standard for Digital Geospatial Metadata (Federal Geographic Data Committee 1998),
- United States National Map Accuracy Standards (U.S. Geological Survey 1999)

Mapping standards include a minimum mapping unit (MMU) of 0.5 ha and a classification accuracy meeting or exceeding 80% (with a 90% confidence level) for map classes representing natural (including ruderal[2]) vegetation types in the U.S. National Vegetation Classification (USNVC). Geospatial products are projected in the Universal Transverse Mercator (UTM) coordinate system and use the North American Datum of 1983 (NAD 83). The NPS VMI Program provides an array of mapping and vegetation data products. Mapping products include aerial imagery, spatial map layers of vegetation, metadata, a map-classification description or key, and a contingency table showing AA results of the vegetation map. Vegetation products include vegetation classification, field key to vegetation types, formal descriptions of vegetation types, and field data of vegetation sampling sites in database format. More information on the NPS VMI Program, including completed vegetation mapping projects, is on the internet at https://www.nps.gov/im/vegetation-inventory.htm. Information on the NPS NRSS IMP is available on the internet at https://www.nps.gov/im/index.htm.

Classification Standard

The NVCS (Federal Geographic Data Committee 2008) is a methodology to classify existing vegetation and is a framework to organize a vegetation classification within a hierarchical structure. The USNVC is a vegetation classification that follows the NVCS to define and organize existing vegetation in the United States. The NVCS is static in its methods and structure, whereas the USNVC is flexible with its vegetation classification concepts and assignments but remains within the static structural hierarchy of the NVCS. The NPS VMI Program uses the USNVC to classify and describe vegetation of national park units to provide a uniform approach in vegetation classification. The use of a national standard aids effective resource stewardship by augmenting compatibility and widespread use of the information throughout the NPS and other Federal and State agencies.

The NVCS separates vegetation into the following two overriding vegetation categories: natural (including ruderal) and cultural. Hierarchical levels for natural and cultural vegetation with examples of vegetation types from the USNVC are listed in Tables 1 and 2. Definitions of these various levels are detailed in section 2 of the NVCS (Federal Geographic Data Committee 2008); however, because of the emphasis given by the NPS VMI Program to vegetation types of the floristic levels (alliance and association) and the group level of the NVCS, the following brief definitions are provided.

- An association-level type is the finest level of the NVCS and is “defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions and physiognomy” (Jennings et al. 2006, as quoted in Federal Geographic Data Committee 2008:14). “Associations reflect topo-edaphic climate, substrates, hydrology, and disturbance regimes” (Federal Geographic Data Committee 2008:14).

[2]Ruderal vegetation is defined as "vegetation found on human-disturbed sites, with no apparent recent historical natural analogs and whose current composition and structure is not a function of continuous cultivation by humans and includes a broadly distinctive characteristic species combination, whether tree, shrub, or herb dominated. The vegetation often consists of invasive species, whether exotic or native, that have expanded in extent and abundance due to the human disturbances." (Faber-Langendoen et al. 2014).

- An alliance-level type is hierarchically one level above the association level and is "defined by a characteristic range of species composition, habitat conditions, physiognomy, and diagnostic species, typically at least one of which is found in the uppermost or dominant stratum of the vegetation" (Jennings et al. 2006, as quoted in Federal Geographic Data Committee 2008:14). "Alliances reflect regional to subregional climate, substrates, hydrology, moisture/nutrient factors, and disturbance regimes" (Federal Geographic Data Committee 2008:14).
- Although a group-level type is hierarchically one level above the alliance level (two levels above association level), the group-level type also is the lowest level of the middle section of the NVCS hierarchy. The group level is defined in Table 2.4 of the NVCS as "combinations of relatively narrow sets of diagnostic plant species (including dominants and codominants), broadly similar composition, and diagnostic growth forms that reflect biogeographic differences in composition and sub-continental to regional differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes" (Federal Geographic Data Committee 2008:17).

Table 1. Hierarchy structure of the National Vegetation Classification Standard, Version 2 (Federal Geographic Data Committee 2008) for natural vegetation with example assignments from the U.S. National Vegetation Classification (NatureServe 2020).*

Classification level	Example
Formation Class	Forest & Woodland (1; C01)
Formation Subclass	Temperate & Boreal Forest & Woodland (1.B; S15)
Formation	Cool Temperate Forest & Woodland (1.B.2; F008)
Division	Eastern North American Forest & Woodland (1.B.2.Na; D008)
Macrogroup	Laurentian-Acadian Mesic Hardwood - Conifer Forest (1.B.2.N1.7; M014)
Group	Central & Southern Appalachian Red Spruce - Fir - Hardwood Forest (1.B.2.Na.7.e; G632)
Alliance	*Picea rubens* - *Abies fraseri* Forest (A0136)
Association	*Abies fraseri* / (*Rhododendron catawbiense*, *Rhododendron carolinianum*) Forest (CEGL006308)

* Fraser Fir Forest (Evergreen Shrub Type) is presented in its full hierarchical classification assignments by the U.S. National Vegetation Classification. The codes that follow classification names are code assignments.

Table 2. Hierarchy structure of the National Vegetation Classification Standard, Version 2 (Federal Geographic Data Committee 2008) for cultural vegetation with example assignments from the U.S. National Vegetation Classification (NatureServe 2020).*

Classification level	Example
Cultural Class	Agricultural & Developed Vegetation (7; CL01)
Cultural Subclass	Woody Agricultural Vegetation (7.A; CSC01)
Cultural Formation	Forest Plantation & Agroforestry (7.A.2; CFO02)
Cultural Subformation	Forest Plantation (7.A.2.1; CSF05)
Cultural Group (optional)	Temperate & Boreal Plantation (7.A.2.1.2; CGR007)
Cultural Subgroup	Eastern North American Temperate Forest Plantation (7.A.2.1.2.a; CSG005)
Cultural Type	Native Miscellaneous Southern Conifer Plantation (7.A.2.1.2.a.5; CTY013)
Cultural Subtype (optional)	Native Miscellaneous Southern Conifer Plantation (CST008544)

* The Native Miscellaneous Southern Conifer Plantation Cultural Subtype is presented in its full hierarchical classification assignments by the U.S. National Vegetation Classification. The codes that follow classification names are code assignments.

Great Smoky Mountains National Park Vegetation Mapping Project

The GRSM vegetation mapping project was initiated by the NPS VMI Program to classify and map vegetation types of GRSM, including the Foothills Parkway, thereby providing the NPS NRSS IMP, resource managers, and biological researchers with useful baseline vegetation information. A previous vegetation mapping project for the Park was completed in 2004 for the NPS VMI Program (Madden et al. 2004). The vegetation classification (White et al. 2003) for the 2004 mapping project served as a classification foundation to the GRSM vegetation mapping project.

The objectives for the GRSM vegetation mapping project were to update the previous vegetation classification with the current USNVC vegetation types and to accurately produce another vegetation map with increased resolution using modern mapping techniques. To accomplish these objectives, the following three main components were necessary: (1) vegetation classification, (2) vegetation mapping, and (3) AA. Each of the three main components is discussed in greater detail in this report. Furthermore, as with any vegetation mapping project, several intermediate steps were inherent to the process. The remainder of this "Introduction and Project Overview" section provides an overview of work undertaken to complete the GRSM vegetation mapping project, including the three main components and some of the more prevalent intermediate steps. This overview is presented in order of sequence; however, some overlap of events intrinsically exists.

Project Boundary

The project boundary extent for the GRSM vegetation mapping project is shown in Figure 2. The project boundary includes the GRSM and the Foothills Parkway, covering an area of 210,875.1 ha. A feature-class layer showing the extent of the project boundary was developed and incorporated into the geodatabase product for the GRSM vegetation mapping project.

Figure 2. Project boundary extent for the Great Smoky Mountains National Park vegetation mapping project.

Study Plan

A detailed study plan for the GRSM vegetation mapping project was submitted to the NPS VMI Program in 2014. The study plan followed a modified version of the "12-Step Guidance for NPS Vegetation Inventories" (version dated March 1, 2013[3]); some steps were not needed because they were completed by prior studies and other steps were needed yet with modification to better address project needs and limits.

Classification of Vegetation

The vegetation classification for this GRSM vegetation mapping project was first developed in 2003 by NatureServe for a previous vegetation mapping project of GRSM (White et al. 2003, Madden et al. 2004). This 2003 classification served as the foundation in support of the following objectives of this project: (1) to update the classification and (2) to map anew the vegetation communities of the Park. The vegetation classification was modified during this GRSM vegetation mapping project based on data from the new mapping and AA efforts. Additional vegetation types were identified during the mapping effort. These vegetation types were documented for the Park by qualified

[3]Version accessed at https://irma.nps.gov/Datastore/Reference/Profile/2252002.

ecologists and then added to the GRSM vegetation classification. Where applicable, vegetation community concepts, names, and codes were updated to the current version of the USNVC.

The 2003 vegetation classification was derived from more than 500 vegetation plots collected between 1977 and 2001; these vegetation plots are referred to as "legacy plots" throughout this report. Vegetation analyses provided detailed ecological information to affirm vegetation associations in the USNVC and to document the vegetation associations with local descriptors. A field key to vegetation types complemented the 2003 vegetation classification. The vegetation classification and field keys were updated and then continually refined throughout the GRSM vegetation mapping project with additional data from map reconnaissance, verification, and AA. Additional vegetation plots were collected in 2016 and 2017 to support vegetation types discovered during map reconnaissance (whether newly discovered at the Park or a variant of an already known type at the Park).

The additional vegetation plots were entered into the PLOTS version 4.0 (National Park Service 2015) database for this GRSM vegetation mapping project. Information on the set of vegetation data used to build the original vegetation classification for the Park resides with White et al. (2003). This GRSM vegetation mapping project identified 112 vegetation types consisting of 105 USNVC association types, 2 "park-special[4]" types, 1 "map-special[5]" type, 1 USNVC cultural subtype that functions as a ruderal forest in the Park, and 3 other USNVC cultural types for agricultural and developed lands. Methods and results of vegetation classification are provided in the "Vegetation Classification" section of this report.

Classification Organization

Throughout this project report and the final products related to the GRSM vegetation mapping project, vegetation types are current to NatureServe (2020), which follows the methodology and organizational hierarchy of the NVCS, version 2 (Federal Geographic Data Committee 2008). The NVCS makes a distinction between natural (including ruderal) and cultural vegetation. Areas with at least 1% vegetation cover are classified and described with the USNVC with one exception—aquatic areas are only included when at least 10% vegetation cover (emergent or submergent) is present. Aquatic areas with less than 10% vegetation cover are categorized as open water; these areas are not described in the USNVC.

[4]A park-special vegetation type is one that lacks robust classification data for inclusion to the International Vegetation Classification and USNVC. However, the status of a park-special vegetation type could change if sufficient classification data were to warrant submission for peer review of potential status in the USNVC.

[5]A map-special vegetation type is not classified to the USNVC. The vegetation in a map-special type lacks the characteristics or consistency needed for definition. Generally, a map-special vegetation is defined by the event that initiated the vegetation, such as response from a recent catastrophic event.

Although park-special vegetation types are technically not included in the USNVC, these vegetation types are listed with the USNVC associations and their likely locations as if part of the USNVC, including hierarchical placement in the USNVC.

The term "vegetation type" is used throughout this report to reference vegetation classification units at any level of the classification hierarchy. For example, the *Abies fraseri* / (*Rhododendron catawbiense*, *Rhododendron carolinianum*) Forest Association, the Native Miscellaneous Southern Conifer Plantation Cultural Subtype, the *Saxifraga michauxii* - *Carex misera* - *Schizachyrium scoparium* Rocky Grassland Alliance, and the Virginia Pine - Table Mountain Pine Woodland & Barrens Group are each referred to as a vegetation type.

Project Orientation Meeting

An orientation meeting was held July 15–16, 2015, at GRSM to discuss the mapping, AA, and end products for the GRSM vegetation mapping project. Cooperators met to achieve the following objectives:

- provide an overview of the NPS VMI Program and data applications;
- become informed of the history, purpose, landscape, management, science, and specific interests of the Park;
- provide an overview of the vegetation sampling and classification work already completed;
- provide an overview of the digital aerial imagery already collected and processed;
- present the major steps remaining for the vegetation mapping project and view examples of final products;
- discuss an action plan for fieldwork and review the project schedule;
- review and become acquainted with the initial vegetation classification that had been developed for GRSM; and
- visit various sites in the Park (Figure 3).

Figure 3. A field visit to a mesic hardwood forest during the orientation meeting for the Great Smoky Mountains National Park vegetation mapping project.

Mapping of Vegetation

The review of the initial vegetation classification during the project orientation meeting prepared the mappers for field reconnaissance—the purpose of which was to visit the vegetation types in the field, discern the appearances of vegetative types in the aerial images, and establish mapping protocols. The mappers completed six 2-week field efforts during 2016 and 2017, assisted intermittently by vegetation ecologists and Park staff for classification guidance (Figure 4). The 2016 field efforts were on the North Carolina side of the Park and the 2017 field efforts were on the Tennessee side. The first two field efforts each year were devoted to collecting information on each individual vegetation type or map class. The third field effort each year focused on the verification process, which included testing draft versions of the vegetation field key and a sampling of preliminary map polygons. The map and vegetation field key were then adjusted based on the verification results.

Figure 4. A vegetation ecologist providing classification guidance to a mapper during field reconnaissance for the Great Smoky Mountains National Park vegetation mapping project.

The mapping proceeded from fall 2016 through spring 2018. Mappers interpreted vegetation and land-cover types by viewing the digital aerial imagery collected for this project. The mappers viewed the aerial imagery stereoscopically by using computer workstations equipped with three-dimensional (3D) and geographic information system (GIS) software. Map conventions based on fieldwork and the vegetation classification helped maintain consistency in mapping. Draft versions of the vegetation map (a spatial database layer) were completed in spring 2017 for the North Carolina side and spring 2018 for the Tennessee side. These map layers were prepared for AA. Areas affected by the Chimney Tops 2 fire (approximately 4,452 ha within the Park), first reported November 23, 2016, were mapped per the prefire imagery based on field notes from areas unaffected by the fire.

A total of 52 map classes represent GRSM, including the Foothills Parkway. Of these 52 map classes, 46 represent natural (including ruderal) vegetation types consisting of 90 USNVC association types, 1 park-special type, 1 map-special type, and 1 USNVC cultural type[6]. For the remaining 6 of the overall 52 map classes, 4 represent USNVC cultural types for agricultural and developed areas, and 2 represent non-USNVC types for nonvegetated open water and nonvegetated rock. The vegetation map layer (covering 210,875 ha) provides 34,084 polygons of detailed attribute data when special modifiers are not considered and 36,589 polygons of detailed attribute data when

[6]The *Picea abies* Forest Plantation Cultural Subtype (CST007167) represented by the Ruderal Norway Spruce Forest (FXNS) map class is included with the natural (including ruderal) types because it is no longer managed as a cultural type at GRSM and functions as a natural ruderal forest.

special modifiers are considered. Methods and results of vegetation mapping are provided in greater detail in the "Vegetation Mapping" section of this report.

Minimum Mapping Units

The standard MMU of 0.5 ha set by the NPS VMI Program was applied to mapping forest and cultural map classes. For woodland, shrubland, herbaceous vegetation, and nonvegetated rock and open-water map classes, an MMU of 0.25 ha was applied. More details on MMU conventions are provided in the "Vegetation Mapping" section of this report.

Accuracy Assessment Study

An AA was completed on draft versions of the vegetation map layer. During the 2017–19 field seasons, field crews collected data from 972 stratified-random sites to evaluate the accuracy of the vegetation map layer for those map classes representing natural (including ruderal) vegetation types. Areas affected by the Chimney Tops 2 fire, an event that happened post-imagery collection for this project, were excluded from the AA process. The AA field data were compared to the vegetation map data, with the initial results reviewed by the AA and mapping teams (Figure 5), and the map data were reconciled as necessary with agreement by NPS staff from GRSM. Results from the AA study indicate an overall accuracy of 80.64% (kappa index of 79.96%, which accounts for chance agreements) based on an analysis of data from 966 of the 972 AA sites. The results were tabulated into a contingency matrix. Methods and results of the AA are provided in greater detail in the "Accuracy Assessment" section of this report.

Figure 5. The accuracy assessment analysis and mapping teams reviewing initial accuracy results of the vegetation map for the Great Smoky Mountains National Park vegetation mapping project.

Product Development and Delivery

The suite of end products developed and compiled for the GRSM vegetation mapping project includes a project geodatabase; orthorectified aerial imagery collected for the project; metadata documentation for geospatial datasets; a digital map book displaying the project aerial imagery; a vegetation database with the formal field data collected during this project (vegetation plots, verification sites, and AA sites); digital images of the formal field data, maps, and graphics showing a representation of each feature class within the project geodatabase; vegetation description report; field key to vegetation types; and this NPS Natural Resource Report summarizing the GRSM vegetation mapping project. The set of products is delivered to NPS staff of the VMI Program, and GRSM. The VMI Program posts the products to the Integrated Resource Management Applications Portal, providing easy access to these end products by the NPS, partners, and public. The GRSM data-product set resides at https://irma.nps.gov/DataStore/Reference/Profile/2165636 and https://www.nps.gov/im/vmi-grsm.htm.

The project geodatabase contains the following five feature classes: (1) polygon features showing the locations of vegetation types and general land-cover features; (2) point features showing the locations of vegetation plots, verification sites, and AA sites; (3) point features showing the locations of aerial image centers to the aerial imagery obtained for the vegetation mapping project; (4) line features showing the locations of flight lines to the aerial imagery obtained for the vegetation mapping project; and (5) polygon features showing the project boundary extent. Included in the geodatabase are tables that provide more information about the features and links to classifications and detailed sampling data. Geospatial products are projected in the UTM coordinate system, Zone 17 North, by using the NAD 83.

Digital Aerial Imagery

Digital aerial imagery provides baseline data for mapping vegetation types and other land-cover features. Vertical imagery (images taken with the aerial camera pointed straight down at the ground) collected with proper overlap for each flight line allows an interpreter to study the images three dimensionally with a stereoscope (Avery 1978) or, as with the GRSM vegetation mapping project, to view digital aerial images in 3D using computers and specialized GIS software. Because ecological settings are considered when mapping vegetation types, viewing the aerial images in 3D helps the interpreter to recognize those ecological settings.

To achieve successful aerial imagery for vegetation mapping purposes, three sets of digital aerial imagery were acquired for the GRSM vegetation mapping project. Each imagery set was collected at different periods during late September through October 2015, to capture peak leaf-phenology change of deciduous trees across the elevation gradient at GRSM, with elevation-gradient zones as follows:

- Peak leaf-phenology change for elevations below 914 meters above msl,
- Peak leaf-phenology change for elevations from 914 to 1,372 meters above msl, and
- Peak leaf-phenology change for elevations above 1,372 meters above msl.

Staff from GRSM provided input on the three collection periods to best capture peak-phenology change of deciduous trees across the elevation range at the Park.

Regardless of the targeted elevation zone to capture peak leaf-phenology change, the goal was to collect aerial imagery of the Park for each imagery set. A minimum of a 100-meter buffer beyond the GRSM study area boundary was included in the aerial imagery flight plans. Figure 6 shows the flight lines over the elevation-gradient zones for the GRSM vegetation mapping project.

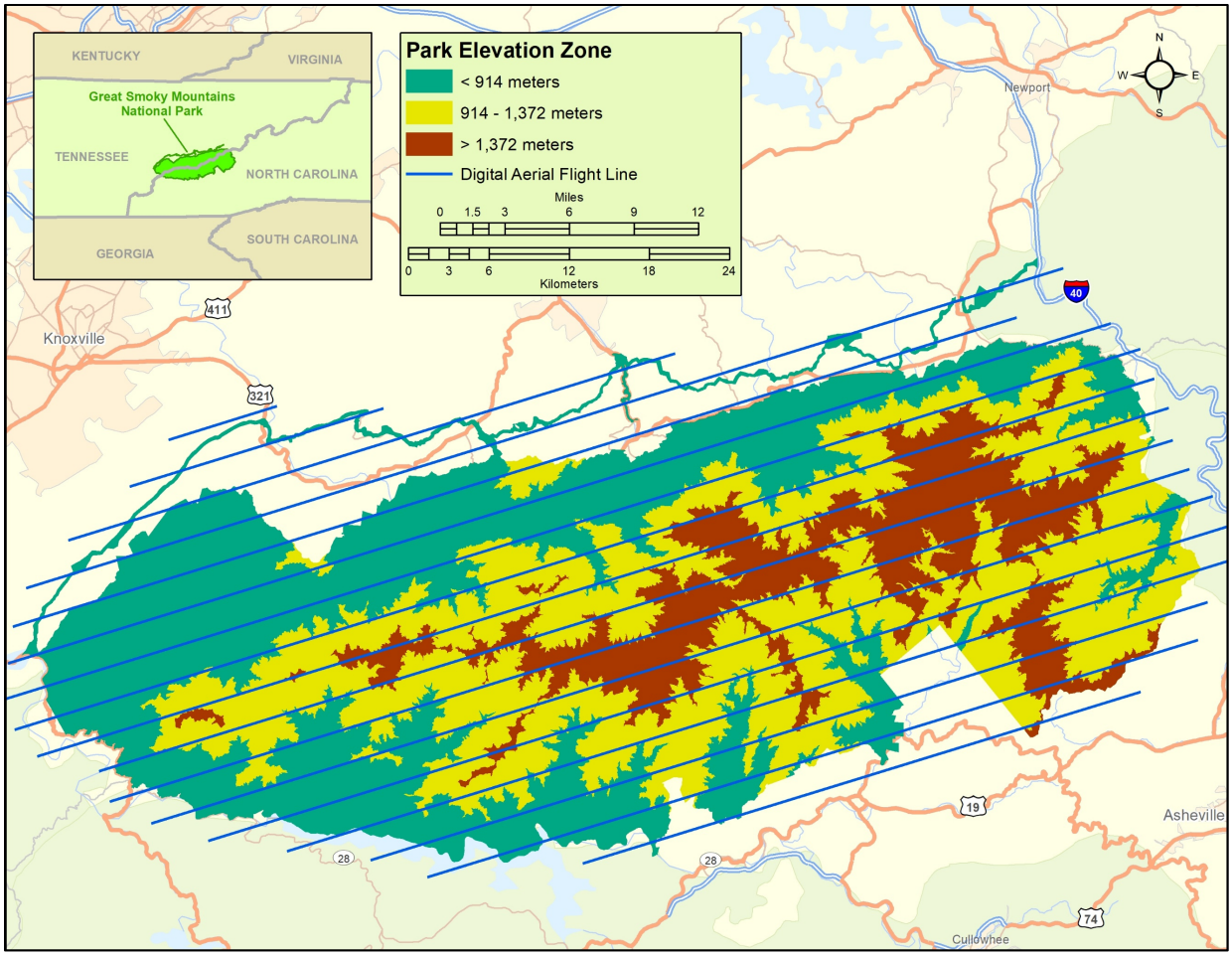

Figure 6. Flight line locations of digital aerial imagery collected for the Great Smoky Mountains National Park vegetation mapping project, shown with three elevation-gradient zones for targeting peak leaf-phenology change.

The three sets of aerial imagery were collected by Quantum Spatial (formerly Photo Science, Inc.) through contract with the U.S. Geological Survey National Geospatial Technical Operations Center. The imagery was acquired with aircraft that was equipped with a gyroscopically-mounted, high-resolution, digital aerial camera system. The camera system captures imagery in four spectral bands including red, green, blue, and near infrared. Having this set of spectral bands allows for viewing the imagery in true color (TC) and color infrared (CIR), which aided mappers in their image interpretation of GRSM vegetation types. The camera system uses a sophisticated inertial

measurement unit and a sensitive global positioning system (GPS) to track the precise location and position of the camera sensor at each instance of exposure. Image processing software uses these positional data to reference each image frame to the surface of the Earth within 1 meter (Ip et al. 2007).

Imagery acquisition parameters included a sun angle greater than 30 degrees off horizon and with conditions free from clouds and cloud shadows, smoke, haze, light streaks, snow, foliage, flooding, and excessive soil moisture. These environmental conditions and peak leaf-phenology stages were monitored by Park staff to regulate the windows of opportunity to capture aerial imagery for each of the three sets of imagery. The imagery sets were collected to achieve a ground sampling distance of 30-centimeter pixel resolution and with a 60% forward lap for stereo viewing and a 40% side lap for adequate coverage with minimal parallax distortion along imagery margins.

The three sets of aerial imagery used for mapping GRSM were collected during September 23–October 6, October 17–19, and October 30, 2015. The first set of aerial imagery (dated September 23–October 6) that captured peak leaf-phenology change at high elevations resulted in partial coverage because of persistent cloud cover during the acquisition window. The second set (dated October 17–19) captured peak leaf-phenology change at middle elevations, and the third set (dated October 30) captured peak leaf-phenology change at low elevations. The second and third sets each captured the project area in its entirety with near-perfect weather and almost no cloud cover. Table 3 provides baseline information about the aerial imagery used for the GRSM vegetation mapping project. The second set of imagery was used as the primary source for image interpretation and mapping, whereas the first and third sets of imagery were used accordingly to view and map vegetation types across the elevation gradient of the Park.

Table 3. Digital aerial imagery sets used to map the Great Smoky Mountains National Park, North Carolina and Tennessee.*

Imagery date	Target elevation above msl (m)	Imagery type	Resolution pixel (cm)	Footprint (pixels)	Image footprint (m)	Image area (ha)
9-23-2015 to 10-6-2015	>1,3771	Four band	30	7,680 by 13,824	2,304 by 4,147.2	955.5
10-17-2015 to 10-19-2015	914–1,371	Four band	30	7,680 by 13,824	2,304 by 4,147.2	955.5
10-30-2015	<914	Four band	30	7,680 by 13,824	2,304 by 4,147.2	955.5

* msl, mean sea level; cm, centimeter; ha, hectare; m, meter

The digital aerial imagery was reviewed to ensure that requirements for mapping purposes were met. Upon acceptance, exposures were adjusted for viewing and interpreting purposes. The aerial imagery was then processed for field and mapping purposes. Processing resulted in the creation of the following two products: (1) orthorectified four-band imagery for background display in a GIS and (2)

stereo models to view and map images in 3D using a GIS and specialized 3D computer hardware and software.

Orthorectified Mosaic

For each of the three aerial imagery sets, individual image tiles were converted to Tagged Image File Format and referenced to the Earth using the camera-generated GPS and inertial measurement unit (IMU) values. Because the IMU records the rotation values from the camera sensor in three directions (roll, pitch, and yaw), and the GPS records the horizontal and vertical values from the sensor at the moment of exposure, specific software programs can reference each digital aerial image precisely to its ground position. To further increase the fit of the images to the Earth, software programs drape each aerial image over the landscape using digital elevation models.

Once referenced, or orthorectified, the individual digital aerial images were color balanced and "stitched" together to form an orthoimage mosaic by flight line for each of three aerial imagery sets. Each orthoimage mosaic was compressed into the JPEG 2000 file format to accommodate computer hardware systems and GIS software with manageable file sizes. The orthoimage mosaics were projected in the UTM coordinate system, Zone 17 North, by using the NAD 83. The aerial imagery mosaics could then be viewed on computers in TC and CIR to aid mappers during fieldwork and mapping (Figure 7).

Figure 7. A mapper viewing aerial imagery on a computer to aid in fieldwork for vegetation mapping.

Stereo Models

Digital aerial images were collected with a 60% overlap of each frame along a flight line. This overlapping coverage of the ground on the images is what allows for the creation of a 3D onscreen view with specialized computer software. Before the aerial imagery can be viewed in 3D, several

processing steps must take place. For the GRSM vegetation mapping project, stereo models were produced using IMAGINE Photogrammetry (ERDAS, Inc.). A stereo model is a flight line of imagery along with a separate georeferencing file called a block file. The block file establishes the relation of each aerial image to the adjacent image in order to precisely align the image pair (also known as a stereo pair) so that the image pair is viewable in 3D and is displayed in the correct geospatial position. When the stereo model is imported into the software program "Stereo Analyst for ArcGIS" (ERDAS, Inc.), the imagery can be viewed in 3D for interpretation and map generation. Because the block file associated with each stereo model contains georeferencing information, the delineations made onscreen by the interpreter also are georeferenced as the delineations are drawn, creating the vegetation map. More information on the use of stereo models with specialized stereo viewing equipment for mapping is provided in the "Vegetation Mapping" section of this report.

In addition to mosaic orthoimages and stereo models, a feature-class layer was produced of the aerial imagery to show in GIS the flight line locations and the center locations of individual aerial images. These feature classes are incorporated into the geodatabase product for the GRSM vegetation mapping project. Aerial orthoimage mosaics are included as products, along with a nonspatial digital map book of aerial images.

Vegetation Classification

A vegetation classification of the Great Smoky Mountains National Park (GRSM, also referred to as the "Park") was initially developed as an independent effort before the mapping and accuracy assessment (AA) for this GRSM vegetation mapping project. The initial vegetation classification (White et al. 2003) was completed by NatureServe and the National Park Service (NPS) for a previous vegetation mapping project of GRSM (Madden et al. 2004). This initial vegetation classification served as a foundation to further classify and map the vegetation types of the Park for this GRSM vegetation mapping project. As this vegetation mapping project proceeded with mapping and AA, additional vegetation types were recognized in the Park, especially because of the addition of the Foothills Parkway to the project, and these vegetation types were added to the vegetation classification for the GRSM vegetation mapping project. Vegetation plots were collected to verify and characterize most of these additional vegetation types. Furthermore, at the close of the vegetation mapping project, classification concepts, names, and codes were updated to the current version of the U.S. National Vegetation Classification (USNVC) (NatureServe 2020), including hierarchical placement. This "Vegetation Classification" section discusses methods and results of vegetation classification for the GRSM vegetation mapping project, including the methodology to develop the vegetation classification prior to the mapping and AA efforts.

Methods

The vegetation classification for the GRSM vegetation mapping project was built from the 2003 classification (White et al. 2003). The 2003 classification was developed of the Park prior to this project from plots and data. To document some classifications gaps, the classification was further developed from plot data that were collected with this project.

Existing Classification

The 2003 vegetation classification developed by NatureServe and NPS was supported with data from 294 full plots and 34 quick plots. (A quick plot is a type of vegetation plot that assesses the major vegetative components without completing a botanical inventory.) Additional information used in the classification included publications of legacy data by the NPS and White and Busing (1993), providing an additional 192 historical vegetation plots.

Staff from GRSM provided an initial review of the 2003 classification for completeness and accuracy. This review was followed by an update to the modern classification standards of the USNVC by NatureServe staff. This updated classification was presented to the mappers by NatureServe and the NPS in May 2016 to prepare mappers in their field reconnaissance. To guide fieldwork, NatureServe generated a list of 22 USNVC vegetation types that potentially were proximal to the Foothills Parkway. These 22 vegetation types are associated primarily with the Central Ridge and Valley Physiographic Province, Rolling Hills Subsection (Keys et al. 1995) and occur primarily on limestone, sandstone, or shale. This initial classification was subsequently tested in the field and refined based on summer 2016 and 2017 field reconnaissance by the mappers.

Field Data Collection 2016 and 2017

Vegetation plots were collected in 2016 and 2017 primarily to document rare types not present in the existing classification and types discovered along the Foothills Parkway that were not documented in the 2003 classification. The field sampling methodology applied in 2016 and 2017 was adapted from field-method standards of the NPS VMI Program (NatureServe 2004). Details are provided therein, and a general summary is provided in this section. Data were collected opportunistically during the 2016 and 2017 field season. A total of 10 vegetation plots were collected. For each plot, location, environmental, and vegetation data were collected. Environmental information about each plot included slope, aspect, soil texture, and evidence of disturbance. Within each plot, the vegetation was visually separated into strata (canopy, subcanopy, tall shrub, short shrub, and herbaceous). Visual estimates were collected for average height and total cover of each stratum and for total cover of the dominant and characteristic species in the plot and each stratum. Percent cover estimates were assigned using cover-scale classes (Table 4). Data from plots were taken from an estimated rectangular area of 20 by 20 meters (400 square meters).

Table 4. Cover-scale classes, codes, and vegetation strata used during vegetation plot sampling to develop the initial vegetation classification of Great Smoky Mountains National Park, North Carolina and Tennessee.*

Cover-scale classes		Vegetation strata	
1	>Trace	T1	Emergent Canopy
2	>0.5–1%	T2	Tree Canopy
3	>1–2%	T3	Subcanopy
4	>2–5%	S1	Tall Shrub (>1–5 m)
5	>5–10%	S2	Short Shrub (<1 m)
6	>10–25%	H	Herbaceous
7	>25–50%	N	Nonvascular
8	>50–75%	V	Vines (lianas)
9	>75–95%	E	Epiphytes
10	>95%	–	

* m, meter

Digital photographs also were collected from the plot to provide additional information and assist in the vegetation classification. Photographs were taken in each cardinal direction from plot center and at least one other additional picture that best captured the character of the vegetation.

These vegetation plots were identified in the field, or shortly thereafter, to a vegetation type. When a vegetation type was determined at a plot, the existing field key to vegetation types of GRSM was used. Furthermore, as fieldwork progressed and vegetation types were identified that were not part of

the initial classification, the field key was revised by NatureServe ecologists in consultation with the mappers and GRSM staff, and new versions of the field key were used on subsequent visits.

Vegetation plot locations were recorded using a Wide Area Augmentation System (WAAS) enabled handheld global positioning system (GPS) unit. Locations of vegetation plots collected for this GRSM vegetation mapping project that support the addition of vegetation classification types are shown in Figure 8. Refer to White and Busing (1993), White et al. (2003), and Madden et al. (2004) for the vegetation data used to develop the initial vegetation classification.

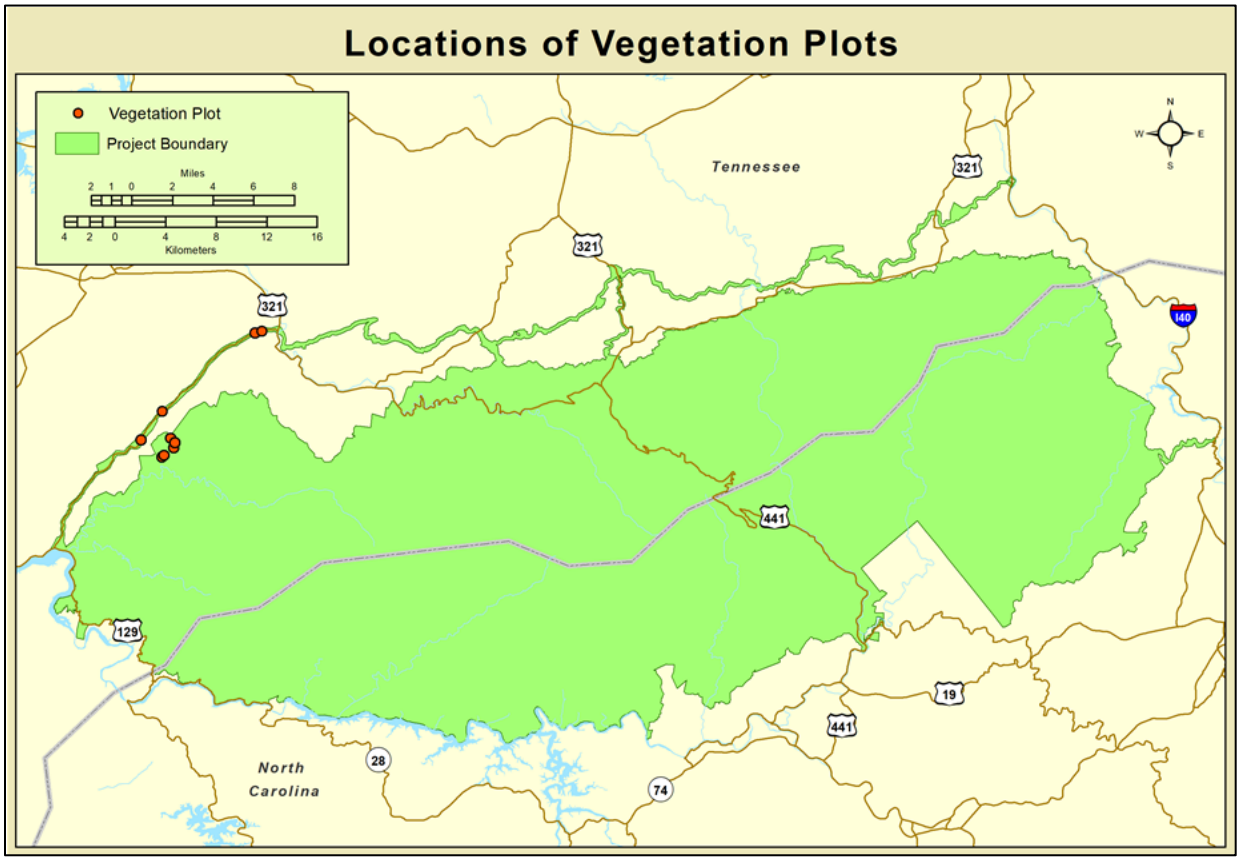

Figure 8. Locations of vegetation plots collected to support additional vegetation classification for the Great Smoky Mountains National Park vegetation mapping project.

Data Entry and Quality Control

Vegetation data from the field forms were checked and then entered into the PLOTS version 4.0 (National Park Service 2015) database for the project. In cases where writing was unclear, fields were highlighted and checked again. Species and cover data entered into the database were subjected to quality control processes to ensure accuracy in the vegetation dataset. The vegetation plot data were not analyzed with multivariate analysis because the number of plots sampled was limited. The plot data were provided to the mappers.

Results

The final version of the vegetation classification for the GRSM vegetation mapping project is discussed in this section. The vegetation classification report, the field key to vegetation types, and the vegetation PLOTS database are each posted to the NPS Integrated Resource Management Applications (IRMA) Portal at the location associated with this GRSM vegetation mapping project (https://irma.nps.gov/DataStore/Reference/Profile/2165636); however, brief explanations of each of these products are provided in this section.

Vegetation Classification Results

A total of 112 vegetation types are recognized for the GRSM vegetation mapping project. The 112 vegetation types consist of 105 USNVC association types, 2 park-special types[7], 1 map-special type[8], and 4 USNVC cultural types[9].

Vegetation Classification Report

The vegetation classification report (NatureServe 2020) provides detailed descriptions for each natural (including ruderal) vegetation type recognized with this GRSM vegetation mapping project. The classification report also includes brief descriptions for each cultural vegetation type recognized with this project. This vegetation classification report is posted to the NPS IRMA Portal at the location associated with this project. The classification report lists each vegetation type hierarchically in the USNVC, followed by concept summaries, environmental and vegetation information, characteristic species, classification development, and distributions. Most fields in the descriptions have separate sections with information on the global characteristics (prefaced by "Global" and referring to its range-wide characteristics) and on the local characteristics (prefaced by "Great Smoky Mountains National Park" and referring to its Park-specific characteristics).

The global information in a vegetation description applies to the range of the vegetation type; this information has been gathered from scientific literature and other field data and is stored in NatureServe's central database. For the descriptive text fields, global information (listed as "Global") can be thought of as an average or modal expression of a natural stand throughout the range of the vegetation type. The local information (listed as "Great Smoky Mountains National Park") is derived from data from the classification phases before and during this GRSM vegetation mapping project.

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[7]A park-special type lacks sufficient classification data for inclusion to the USNVC. More robust data could warrant potential status in the USNVC as an association.

[8]This map-special type was not placed in the USNVC. The type was made into a map-special type to map non-directional vegetation response to eastern hemlock (*Tsuga canadensis*) stands of total mortality from infestation by non-native insects.

[9]However, the *Picea abies* Forest Plantation Cultural Subtype (CST007167) was treated as a natural (including ruderal) vegetation type for the GRSM vegetation mapping project because it is no longer managed as a cultural type and functions as a natural ruderal forest.

These data consisted mostly of data from the plots sampled before and during this project; however, some information from AA field data and less formal field observations also are included.

For each description of a vegetation type, "Local" and "Global" descriptions are given in the "Environment," "Vegetation," and "Range" sections. Additional fields in the database were updated as additional data were gathered, including "Other Noteworthy Species" (such as rare or exotic taxa) and "Summary." For each vegetation type, the most abundant species were listed according to stratum (such as canopy and subcanopy) and lifeform (such as forb and graminoid).

Field Key to Vegetation Types

The field key to vegetation types (White et al. 2020) consists of dichotomous options that lead to natural (including ruderal) vegetation types recognized with this GRSM vegetation mapping project. This field key is posted to the NPS IRMA Portal at the location associated with this project. The vegetation classification report (NatureServe 2020) complements the field key to aid in correct classification assignment.

Vegetation PLOTS Database

The vegetation PLOTS database includes the field-sampling data collected specifically for this GRSM vegetation mapping project. This database is posted to the NPS IRMA Portal at the location associated with this project. The vegetation PLOTS database embodies the recorded field data from vegetation plots collected during the 2016 and 2017 field seasons, and from AA sites collected during the 2017, 2018, and 2019 field seasons.

Listing of Plant Species

The plant species recorded at field-sampling locations (vegetation plots and AA sites) are included in the vegetation PLOTS database and can be exported into a user-derived listing. The plant species also are listed in a table within the project geodatabase, providing another access option to derive a listing of plant species recorded with this project. The project geodatabase is posted to the NPS IRMA Portal at the location associated with this project.

The plant species recorded in the vegetation PLOTS database and the project geodatabase is not intended to be a comprehensive list of every taxon within the Park. However, at least one new vascular species was added to the Park plant list as a result of field work—bog bulrush (*Schoenoplectiella mucronata*).

Vegetation Mapping

This "Vegetation Mapping" section discusses methods and results of vegetation mapping for the Great Smoky Mountains National Park (GRSM, also referred to as the "Park") vegetation mapping project and concludes with an analysis, discussion, and presentation of the map layer.

Methods

Mapping vegetation of GRSM involved the following five primary steps: (1) preliminary map classification with a vegetation primer, (2) field reconnaissance, (3) map classification, (4) aerial image interpretation and mapping, and (5) database development of the map layer. Although these steps proceeded sequentially, the steps overlap to some degree. The vegetation of GRSM was mapped by a mapping team at the U.S. Geological Survey Upper Midwest Environmental Sciences Center.

Preliminary Map Classification

Prior to field reconnaissance, mappers needed to become familiar with the vegetation types expected to exist in GRSM. To accomplish this familiarity for the Park, the mappers met with project vegetation classifiers, Park staff, and local experts. The group reviewed the vegetation classification and the field key to vegetation types that had been previously developed by NatureServe (White et al. 2003), but updated to the newest standards of the U.S. National Vegetation Classification (USNVC). During this meeting, each vegetation type was discussed. For each vegetation type, the discussion included what defines the type, where the type was known or expected to exist within the Park, what other vegetation types are likely to be confused with the type, and any other aspects that could help define the type's location or aerial imagery signature on the landscape. Using this information, the mappers began developing a working map classification to test, update, and refine during field reconnaissance.

Field Reconnaissance

Field reconnaissance efforts were initiated to prepare for mapping vegetation types in GRSM. Mappers visited numerous locations within the Park, often joined by a classifier and Park staff to assist in field classification of vegetation. With the aid of weatherized field computers, the mappers compared the ground conditions to vegetation signatures (appearances) on the digital aerial imagery sets that were obtained in 2015 for this GRSM vegetation mapping project. Vegetation types were determined by a vegetation field key and the classifier. This process was necessary, as Hershey and Befort (1995) explain, because photography (or imagery) is not consistent among image sets to allow a species to be depicted precisely. Sun angle, light intensity, shadow, exposure, and difference in digital postcapture processing can affect image appearance. Differences in site history, hydrologic regime, intraspecific variation, and seasonality can change the appearance of a single species across a single image. Hence, ground exploration of the landscape represented in the imagery is a critical endeavor. The field reconnaissance effort at the Park helped correlate the aerial imagery signatures of the vegetation with the vegetation classification on the ground (Figure 9).

Figure 9. Field reconnaissance to correlate aerial image signatures with ground vegetation for the Great Smoky Mountains National Park vegetation mapping project.

Field reconnaissance also allowed mappers to become familiar with the local ecology of vegetation types, which is helpful when applying ecologic concepts to mapping. Where mappers discovered limitations to interpreting vegetation types using digital aerial imagery, environmental models were tested to determine if vegetation types could be consistently separated by environmental elements. In GRSM, the complexity of terrain and diversity of vegetation and plant species coupled with the history of disturbance (man-made and natural) that pervades the Park has prevented geospatial-based models from being a reliable tool for aerial imagery interpretation.

The mappers and classifier proceeded with field reconnaissance at GRSM during 2016 and 2017. The field efforts for mapping were completed during six trips; three trips to the North Carolina side in 2016 and three trips to the Tennessee side in 2017. The first trip of each year, in May or June, included the project orientation meeting to recognize vegetation differences on the respective side of the Park. The second trip, in June or July, focused on continuing to learn vegetation signatures and signature variations missed during the first trip. The third trip, in August or September, focused on the verification process, which tested a draft version of the vegetation field key and a sampling of preliminary map polygons. The third trip also included additional opportunities for note collection. The mappers and classifier worked as a team, rather than as individuals, to ensure correct assessment of vegetation types and, subsequently, to promote correct classification during mapping. To become familiar with the vegetation and local ecology, the team discussed the structural, floristic, and habitat characteristics of the vegetation present in the field and compared the vegetation types to the

appearance of the vegetation in the imagery. Through this process, the team built an understanding of how to map the vegetation types, how to establish a working map classification with mapping protocols, and how to help the classifier to refine the vegetation classification and the field key to vegetation types.

During the field reconnaissance, the mappers studied a representative sample of the landscape of GRSM and determined much variability within vegetation types. In some cases, the classifier determined that some vegetation types existed that had not been represented by the vegetation plots or that were not fully addressed in existing descriptions in the vegetation classification. These vegetation types were added accordingly to the vegetation and map classifications. During the 6 field reconnaissance efforts, the number of recognized vegetation types within the Park increased from 99 to 112 with significant refinement to the vegetation classification.

Project orthoimagery mosaic sets with four-band (viewable in true color and color infrared) digital aerial imagery allowed for easy use in the field. This imagery was accessed using ArcMap in ArcGIS (Version 10.6, Esri), which also allowed the mapping team to digitally collect notes on vegetation and imagery signatures in the field, such as recording the map-class assignment, if known. Notes to promote proper perspective of species composition, such as comments regarding significant species, also were recorded. An example of species composition is heterogeneous versus monotypic forest stand.

Verification

Between the second and third reconnaissance efforts each year, areas of GRSM with familiar and novel signatures were mapped for field verification. The four-band digital aerial imagery collected for the GRSM vegetation mapping project was interpreted by the mappers, who applied the mapping conventions established from the earlier field reconnaissance effort. During the third field reconnaissance effort each year, the mappers and classifier visited sites to verify that the mapping was correct and that the field key to vegetation types functioned correctly.

A total of 203 verification sites were assessed within GRSM. Specific map verification sites were selected in the field during the third field reconnaissance effort each year. Locations of verification sites (Figure 10) were chosen in an attempt to cover the suite of vegetation types present across the Park's extensive topographic and elevation variation. At each verification site, field data were collected, and the field key to vegetation types, map classification, and mapping conventions were assessed and adjusted as needed. The mappers and classifier collected coordinate location information using field computers equipped with global positioning system (GPS) in conjunction with the digital aerial imagery. A field key to vegetation types of GRSM was used to determine the vegetation type of the area greater than a minimum mapping unit (MMU). The vegetation type was compared to the map class assigned by the mappers, and an electronic data sheet was completed for each verification site. These data were entered into a feature-class layer with relate tables and were incorporated into the geodatabase for the GRSM vegetation mapping project. The field data also were imported into the PLOTS version 4.0 (National Park Service 2015) database for the project.

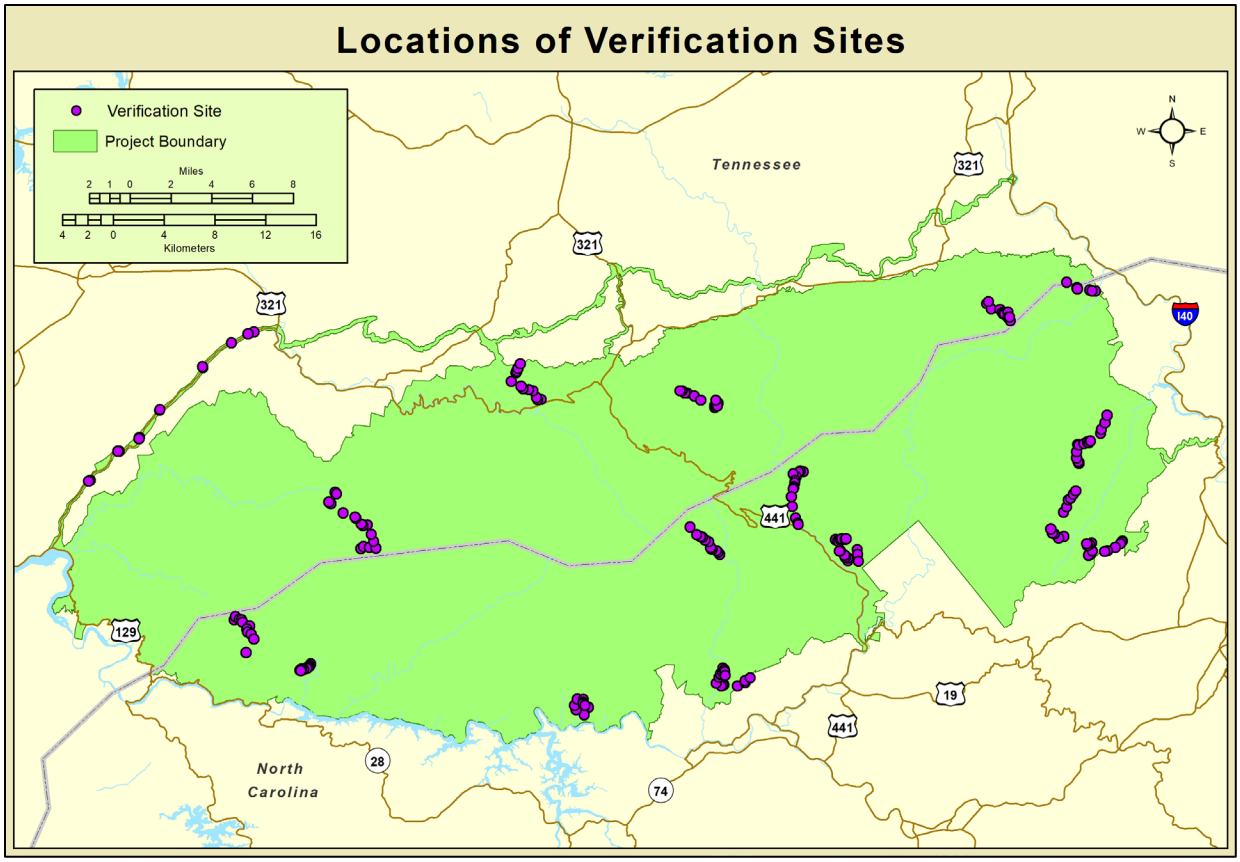

Figure 10. Locations of verification sites for the Great Smoky Mountains National Park vegetation mapping project.

Map Classification

A map class represents a definable feature (e.g., a vegetation type, a nonvegetated feature, and an anthropogenic area) that can be consistently distinguished on aerial imagery or by use of an environmental model, or both. The set of map classes that represents all the mapped features defines the map classification. The map classification and protocols that define the mappable features are based on existing classification systems. For the GRSM vegetation mapping project, all map classes representing vegetation were linked to the vegetation types in either the USNVC or in NatureServe's internal databases (for park-special types). For natural (including ruderal) vegetation, map classes were linked to natural types in the USNVC or NatureServe databases at the finest (lowest) level possible. For cultural vegetation, a map class was linked to a cultural type in the USNVC at the lowest applicable level.

After a draft of the map classification was developed, a "mapping tree" was created to facilitate the mapping process (Figure 11, also provided as a stand-alone file for viewing and printing accessibility). A mapping tree is a diagram that divides the map classes into logical groups (e.g., Oak Forest, Upland Ruderal Forest, and Herbaceous) and then further divides the groups into subgroups (e.g., Red or White Oak [or both], Deciduous Monocultures, and Mowed or Grazed), with a final selection of choices among the similar map classes in each subgroup. The choices in a mapping tree

are meant to present the mappers with a limited and consistent set of options and to remind the mappers of possible alternative map classes.

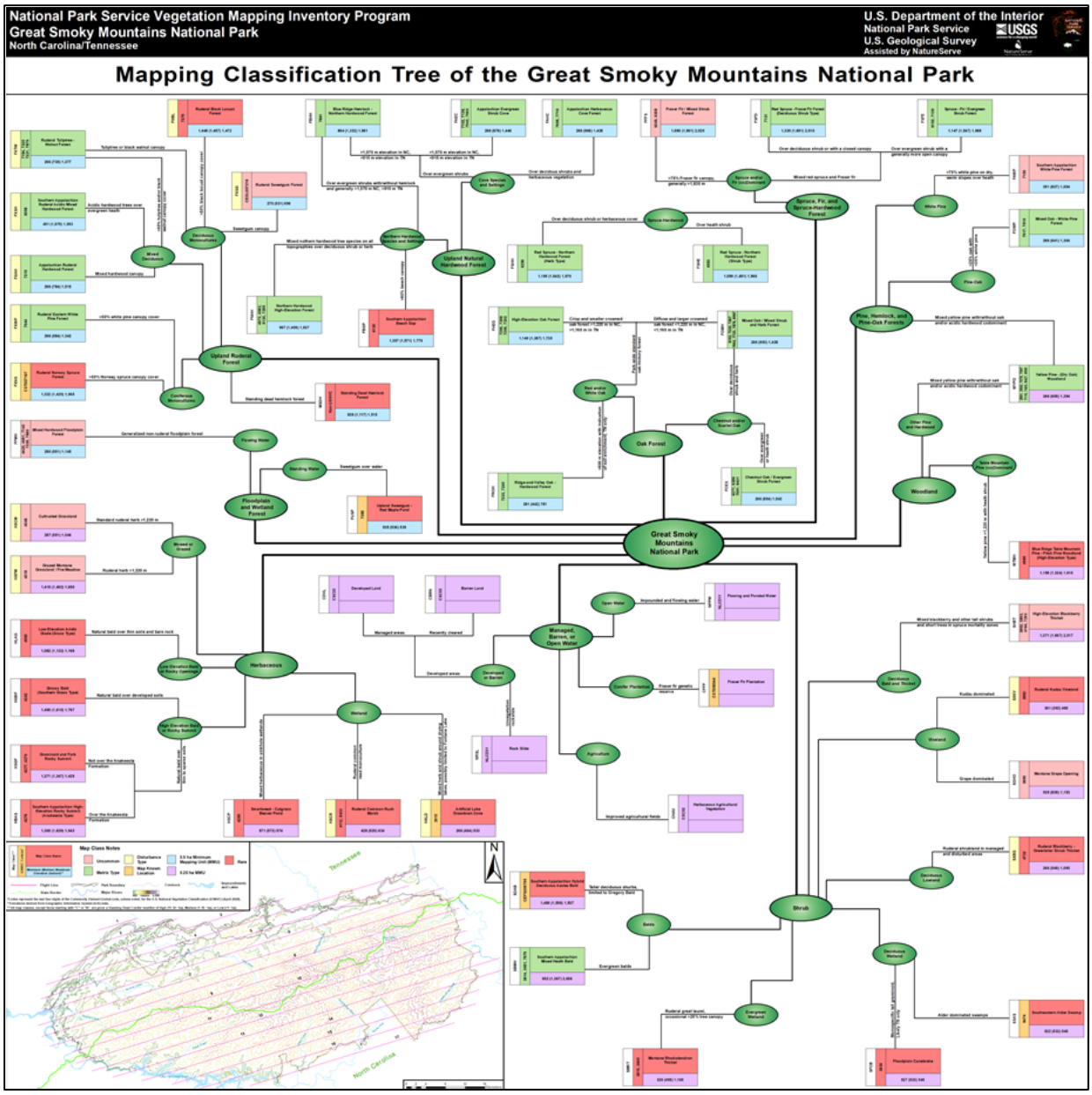

Figure 11. Vegetation mapping decision tree for the Great Smoky Mountains National Park vegetation mapping project. (This figure also is provided as a stand-alone file for viewing and printing accessibility.)

To develop map-class names, for those map classes representing a single vegetation type in the USNVC, the type's common name was used (e.g., Southern Appalachian Beech Gap). For those map classes representing more than one vegetation type, a comparable name (e.g., the Mixed Oak - White Pine Forest map class for the collective USNVC associations of Appalachian White Pine - Mesic Oak Forest and Appalachian White Pine - Xeric Oak Forest) was derived. For map classes

representing cultural vegetation, a generic name (i.e., Developed Land) was derived. For the map classes representing non-USNVC features, a generic name (i.e., Flowing and Ponded Water) was derived.

Throughout the project, the map classification remained fluid. Each field endeavor, including the accuracy assessment (AA) effort, revealed new information that prompted modifications to the map classes and corresponding definitions. Revisions also were made to the map classification as the vegetation classification matured; as aerial images were interpreted, new problems forced redefinition, expansion, conjunction, or minor adjustment to map-class definitions. As individual map classes changed, these changes were consistently reapplied to areas that previously had been mapped to ensure consistent mapping throughout the Park.

A map-class code was derived for each map class for ease of assigning information to map polygons. Each map-class code was made using four alpha characters, and the code was to represent an independent map class; each code was to begin with one of the following first alpha characters to represent the major physiognomic characteristic:

- F—Forest (typically greater than 60% tree cover),
- W—Woodland (greater than 25% tree cover),
- S—Shrubland (greater than 25% shrub cover and less than 25% tree cover),
- H—Herbaceous Vegetation (greater than10% herbaceous cover and less than 25% tree or shrub cover),
- C—Cultural (developed landscapes),
- M—Modified landscapes (catastrophically modified landscapes), and
- N—Non-USNVC (open water with less than 10% vegetation cover).

The second character was to represent one of the following two possible scenarios: (1) to denote a ruderal map class with an "X" or (2) to denote the first significant term in the map-class name. The subsequent two characters loosely represent latter significant terms in the map-class name (e.g., FHEO for High-Elevation Oak Forest, SXKV for Ruderal Kudzu Vineland, CDVL for Developed Land, and NFPW for Flowing and Ponded Water).

A special modifier also was derived to describe coverage per hectare of standing-dead conifer trees. This modifier provides additional information describing conifer mortality still standing within mapped polygons. The special modifier names and corresponding meanings used for the GRSM vegetation mapping project are described in Table 5.

An example of codes assigned to a particular mapped polygon might be "FBHH" (map class) and "High" (physiognomic dead-conifer modifier). The "FBHH" map-class code designates the polygon with the Blue Ridge Hemlock - Northern Hardwood Forest map class, which represents the *Betula alleghaniensis* - (*Tsuga canadensis*) / *Rhododendron maximum* / (*Leucothoe fontanesiana*) Forest (CEGL007861) in the USNVC. The "High" modifier code indicates that the vegetation has more than 30 standing-dead conifers per hectare. This series of map classification and physiognomic

information can enhance the interpretation of the map layer for managers and researchers, particularly when other geospatial datasets are introduced.

Table 5. Standing-dead conifer tree coverage modifier names and corresponding meanings for the Great Smoky Mountains National Park vegetation mapping project.

Modifier name	Modifier meaning
None	Less than 1 per hectare
Low	1–10 per hectare
Medium	10–30 per hectare
High	More than 30 per hectare

Aerial Image Interpretation and Mapping

The vegetation of GRSM was mapped using digital-onscreen three-dimensional (3D) mapping systems running geographic information system (GIS) software. The mapping team performed onscreen interpretation of digital imagery that was spatially referenced in GIS. The mapping tree was used to further assist the mapping process and enforce consistent application of the map classification. A draft version of the vegetation map—a spatial-database layer—was then prepared for AA. The vegetation map was then adjusted according to the results from the analysis of the AA to meet accuracy criteria set by the National Park Service (NPS) Vegetation Mapping Inventory (VMI) Program.

The digital aerial imagery used for the onscreen mapping was collected during the fall of 2015 using a plane-mounted digital camera. (Refer to the "Introduction and Project Overview" section of this report for more information on the digital aerial imagery collected for the GRSM vegetation mapping project.) The mappers used systems that incorporated passive stereo technology that uses polarized glasses to produce a 3D image on a liquid-crystal-display monitor for a computer. The stereo models were imported into the software program "Stereo Analyst for ArcGIS" (ERDAS, Inc.) for 3D viewing and editing.

Mapping proceeded from fall 2016 through spring 2018. A mapper would map a specified area and then give this draft work to a second mapper for quality assurance/quality control (QA/QC). The second mapper would then assess the draft work for errors in mapping and return the draft to the initial mapper for review and modification. The QA/QC process was completed by three mappers; therefore, the tasks were rotated among the mappers in a round-robin manner to ensure consistency among the different mappers. Areas of considerable complexity could be revised more than once. This review process ensured that all portions of GRSM were assessed at least twice and by different individuals.

ArcGIS software was used as the GIS platform for the onscreen digital mapping. Because the 3D images were viewed directly in the GIS environment, vegetation could be mapped directly in ArcGIS. The polygon vector data were stored using an ArcGIS file geodatabase, which was projected

in the Universal Transverse Mercator (UTM) coordinate system, Zone 17 North, by using the North American Datum of 1983 (NAD 83).

Standard image signature characteristics were applied—including texture, color, pattern, and position in the landscape—to guide placement of polygons during mapping. In addition to image signature characteristics, mappers needed to understand the environmental distribution of the vegetation types across the landscape to help identify those vegetation types and to properly place polygon boundaries. For each polygon, the appropriate map-class code was applied.

Supplemental imagery and datasets also were used by the mappers to visualize and understand the landscape. These layers increased the mappers' ability to understand historical landscape change and use, determine wet and dry areas, and better visualize evergreen vegetation. Supplemental data included digital aerial imagery, field reconnaissance data, vegetation plot data, and verification site data. Although an original vegetation map exists for the Park (Madden et al. 2004), the mapping team determined that the direct use of the mapping data would be problematic for three reasons. First, the imagery that was used to create the original map was collected more than 18 years before this mapping project began. This time lapse led to significant change in the Park's land cover because of storms, invasive species, and growth and senescence. Second, the methods used to create the original map make it exceptionally difficult to associate map classes to the USNVC. The original map consisted of 170 association-level overstory vegetation classes and 196 understory association-level vegetation classes, which were collapsed into 24 and 14 classes, respectively. The classes were then approximated to the alliance-level of the USNVC, with the alliance-level completely transformed in the last 10 years. Third, the available point data from the original mapping project were ingested into the new mapping process as an ancillary dataset, but these data were determined to contain numerous spatial errors attributed to early GPS unit accuracy issue. Overall, because of these issues, the mappers were concerned about the applicability of using the original vegetation map as a guide for the new map. Therefore, the decision was made to only use the original point data to assist in the new mapping process.

The NPS VMI Program's standard MMU of 0.5 hectare (ha) was applied to forest map classes. An MMU of 0.25 ha was applied to woodland, shrubland, herbaceous vegetation, cultural areas, and nonvegetated map classes. The smaller MMU was applied because of the consistent small patch presentation of vegetation types represented by the map classes.

For polygons that represent vegetation crossing outside the boundary for the GRSM vegetation mapping project, mappers allowed the polygons to be mapped less than the MMU if the vegetation that continued during the project boundary was contiguous and covered at least the standard MMU for that map class. In these instances, map classes with a 0.5-ha MMU were mapped to 0.1 ha, and map classes with a 0.25-ha MMU were mapped down to 0.05 ha. For example, a 0.18-ha polygon of the Ruderal Tuliptree - Walnut Forest (FXTW) map class would be mapped inside the boundary if at least 0.32 ha of contiguous connected FXTW was outside the boundary.

Chimney Tops 2 Fire

The Chimney Tops 2 fire started in the Tennessee portion of the GRSM on November 23, 2016, about 1 year after the collection of project aerial imagery. This fire created a vast "burn scar" in the vegetation of the Park that did not exist on project imagery. After consultation with Park staff, the project mappers decided to map this area per the project imagery and not the burn hole. To account for the lack of data on the ground and vegetation changes in the burn hole, this area was excluded from the AA process and remains untested. However, the vegetation map of the burn hole provides a picture for the Park of vegetation types and locations directly prior to the fire to assist the Park and future researchers with post-fire analysis and recovery planning.

Database Development

At this stage in the development of the map layer, only map-attribute codes assigned to each polygon existed. To assign meaningful information to each polygon (e.g., map-class names and links to USNVC types), a feature-class table and other supportive tables were produced, and ArcGIS was used to relate the tables of polygon information within a geodatabase. A geodatabase provides access to a variety of interrelated datasets. The geodatabase is expandable and can provide resource managers and researchers with a powerful GIS tool. The geodatabase developed for the GRSM vegetation mapping project includes many feature-class layers produced from this project, including the map layer, vegetation plots, map verification sites, AA sites, aerial image locations, aerial flight line locations, and project boundary extent. Geospatial products for the GRSM vegetation mapping project have been projected in the UTM coordinate system, Zone 17 North, by using the NAD 83.

Results

The final map classification for the GRSM vegetation mapping project is presented in this "Results" section. A summary report of map-class distribution across the vegetation map also is presented in this section.

Map Classes

After reconciling map classes from the AA analysis, 52 map classes represent GRSM; 46 of the 52 map classes represent natural (including ruderal) vegetation types, most of which types are recognized in the USNVC. At the time of mapping, 58 map classes existed to map the Park, of which 52 map classes represented natural vegetation types. The AA study determined that confusion in mapping existed among some map classes; these map classes were listed with accuracy levels less than 80% (in the 90% confidence interval), as set by the NPS VMI Program. Map classes with low accuracy were assessed for consistent sources of error, and then NPS staff from GRSM were consulted to determine if map classes should be merged to reduce error rates. The map classes with low accuracies were merged with other map classes most often confused with during the mapping, unless the lower accuracy was accepted by NPS staff. Several reasons are recognized for where confusion in mapping existed among the map classes, including a breakdown of the mapping tree or ecological mapping conventions, inconsistent signatures on the aerial imagery across and among map classes, and disagreement in classification between field reconnaissance and AA. Further details regarding the mapping confusion are provided in the "Accuracy Assessment" section of this report and in individual map-class descriptions in "Appendix B: Descriptions of Map Classes." The

descriptions in Appendix B also explain the link between map classes and the vegetation types the map classes represent. Ground photograph images showing representations of the map classes are provided where possible.

Of the 52 map classes that represent GRSM, 46 represent natural (including ruderal) vegetation types, consisting of 90 USNVC association types, 1 park-special type, 1 map-special type, and 1 USNVC cultural type[10]. For the remaining 6 of the overall 52 map classes, 4 represent USNVC cultural types for agricultural and developed areas, and 2 represent non-USNVC types for nonvegetated open water and nonvegetated rock. Of the 46 map classes representing natural (including ruderal) vegetation types, 27 represent a single vegetation type (when the type exists above an MMU), 9 represent 2 vegetation types mapped together, 1 represents 3 vegetation types mapped together, 6 represent 4 vegetation types mapped together, 1 represents 5 vegetation types mapped together, 1 represents 7 vegetation types mapped together, and 1 represents 9 vegetation types mapped together.

The map classification for the GRSM vegetation mapping project is listed in "Appendix B: Descriptions of Map Classes."

Summary Report of the Map Layer

Covering 210,875 ha, the vegetation map layer provides 34,084 polygons of detailed attribute data when physiognomic cover-density modifiers are not considered and 36,589 polygons of detailed attribute data when cover-density modifiers are considered.

The spatial-data layer (vegetation map) is summarized for each individual map class at the map-class attribution level, without special modifiers. The frequency of polygons, area, average polygon size, and percent map coverages for each map class are summarized in Table 6.

[10]The *Picea abies* Forest Plantation Cultural Subtype (CST007167) represented by the FXNS map class is included with the natural (including ruderal) types because it is no longer managed as a cultural type at GRSM and functions as a natural ruderal forest.

Table 6. Frequencies of polygons and areas for map classes represented in the vegetation map layer for the Great Smoky Mountains National Park vegetation mapping project.*

Map-class category	Map-class code – name	Poly freq	Area (ha)	Ave (ha)	Prct cover
High-Elevation Deciduous Forest & Woodland	FBGP – Southern Appalachian Beech Gap	91	185.1	2.0	0.1
	FNHH – Northern Hardwood High-Elevation Forest	1,864	13,483.7	6.6	6.4
	FHEO – High-Elevation Oak Forest	359	7,866.2	21.6	3.7
High-Elevation Mixed Deciduous-Conifer Forest	FBHH – Blue Ridge Hemlock - Northern Hardwood Forest	1,085	21,340.0	10.8	10.1
	FSHE – Red Spruce - Northern Hardwood Forest (Shrub Type)	933	6,255.7	6.0	3.0
	FSHH – Red Spruce - Northern Hardwood Forest (Herb Type)	625	5,699.7	8.1	2.7
High-Elevation Spruce-Fir Forest & Woodland	FFFS – Fraser Fir / Mixed Shrub Forest	57	279.7	4.2	0.1
	FSFD – Red Spruce - Fraser Fir Forest (Deciduous Shrub Type)	482	2,287.0	4.3	1.1
	FSFE – Spruce - Fir / Evergreen Shrub Forest	5,340	2,089.7	3.8	1.0
High-Elevation Pine Woodland	WTMH – Blue Ridge Table Mountain Pine - Pitch Pine Woodland (High-Elevation Type)	95	159.6	1.7	0.1
Low-Elevation Oak Forest	FCES – Chestnut Oak / Evergreen Shrub Forest	4,511	59,794.6	12.9	28.4
	FOHM – Mixed Oak / Mixed Shrub and Herb Forest	4,734	24,708.5	5.2	11.7
	FROH – Ridge-and-Valley Oak - Hardwood Forest	11	16.9	1.5	0.008
Low-Elevation Hardwood Forest	FAHC – Appalachian Herbaceous Cove Forest	2,695	8,793.7	3.2	4.2
Low-Elevation Mixed Deciduous-Conifer Forest	FOWP – Mixed Oak - White Pine Forest	2,475	5,908.8	2.4	2.8
	FAEC – Appalachian Evergreen Shrub Cove Forest	1,744	19,936.1	7.7	9.5
Low-Elevation Pine Forest	FAWP – Southern Appalachian White Pine Forest	11	20.0	1.8	0.009

* Tally results represent the vegetation map layer at the map-class attribution level, without special modifiers. The bold headings within the table (above the map classes) are categories to organize the map classes. Poly, polygon; Freq, frequency; ha, hectare; Ave, average; Prct, percent; ~, about

Table 6 (continued). Frequencies of polygons and areas for map classes represented in the vegetation map layer for the Great Smoky Mountains National Park vegetation mapping project.*

Map-class category	Map-class code – name	Poly freq	Area (ha)	Ave (ha)	Prct cover
Low-Elevation Pine Woodland	WYPO – Yellow Pine - (Dry Oak) Woodland	4,996	9,268.1	1.8	4.4
Floodplain Forest	FFMH – Mixed Hardwood Floodplain Forest	143	276.7	1.9	0.1
Wetland Forest	FUSP – Upland Sweetgum - Red Maple Pond	1	2.3	2.3	0.001
Ruderal Deciduous Forest	FXSH – Southern Appalachian Ruderal Acidic Mixed Hardwood Forest	420	1,286.3	3.0	0.6
	FXTW – Ruderal Tuliptree - Walnut Forest	2,196	9,788.4	4.4	4.6
	FXAH – Appalachian Ruderal Hardwood Forest	1,514	4,159.5	2.7	2.0
	FXBL – Ruderal Black Locust Forest	2	1.3	0.6	0.0006
	FXSG – Ruderal Sweetgum Forest	20	29.6	1.5	0.01
Ruderal Conifer Forest	FXWP – Ruderal Eastern White Pine Forest	982	2,179.3	2.2	1.0
	FXNS – Ruderal Norway Spruce Forest	5	5.0	1.0	0.002
High-Elevation Shrub & Herbaceous	SBMH – Southern Appalachian Mixed Heath Bald	645	691.5	1.1	0.3
	SDAB – Southern Appalachian Hybrid Deciduous Azalea Bald	1	1.3	1.3	0.0006
	SHBT – High-Elevation Blackberry Thicket	68	52.4	0.8	0.02
	HGBF – Grassy Bald (Southern Grass Type)	5	3.7	0.7	0.002
	HSGF – Graminoid and Forb Rocky Summit	1	0.5	0.5	0.0002
	HBAS – Southern Appalachian High-Elevation Rocky Summit (Anakeesta Type)	41	20.6	0.5	0.01
Low-Elevation Shrub & Herbaceous	SMRT – Montane Rhododendron Thicket	12	17.9	1.5	0.009
	SGHO – Montane Grape Opening	232	360.8	1.6	0.2

* Tally results represent the vegetation map layer at the map-class attribution level, without special modifiers. The bold headings within the table (above the map classes) are categories to organize the map classes. Poly, polygon; Freq, frequency; ha, hectare; Ave, average; Prct, percent; ~, about

Table 6 (continued). Frequencies of polygons and areas for map classes represented in the vegetation map layer for the Great Smoky Mountains National Park vegetation mapping project.*

Map-class category	Map-class code – name	Poly freq	Area (ha)	Ave (ha)	Prct cover
Low-Elevation Shrub & Herbaceous (continued)	SFCB – Floodplain Canebrake	6	1.8	0.3	0.0009
	HLAG – Low-Elevation Acidic Glade (Grass Type)	1	0.3	0.3	0.0002
Wetland Shrub & Herbaceous	SSAS – Southeastern Alder Swamp	4	2.4	0.6	0.001
	HXCR – Ruderal Common Rush Marsh	7	8.2	1.2	0.004
	HSCP – Smartweed - Cutgrass Beaver Pond	1	0.4	0.4	0.0002
Ruderal Upland & Wetland Shrub & Herbaceous	SXBG – Ruderal Blackberry - Greenbrier Shrub Thicket	56	44.7	0.8	0.02
	SXKV – Ruderal Kudzu Vineland	3	1.8	0.6	0.0009
	HXFM – Grazed Montane Grassland / Fire Meadow	11	16.1	1.2	0.008
	HXCM – Cultivated Grassland	74	854.9	11.6	0.4
	HXLD – Artificial Lake Drawdown Zone	10	9.6	1.0	0.005
Map-Special Vegetation	MSDH – Standing Dead Hemlock Forest	34	61.1	1.8	0.03
Cultural Vegetation	CFFP – Fraser Fir Plantation	2	1.5	0.8	0.0007
	CHAV – Herbaceous Agricultural Vegetation	5	15.2	3.0	0.007
	CBRN – Barren Land	24	274.4	11.4	0.1
	CDVL – Developed Land	228	986.3	4.3	0.5
Rock	NRSL – Rock Slide	8	16.4	2.0	0.008
Water	NFPW – Flowing and Ponded Water	20	1,609.5	80.5	0.8
Totals	–	34,084	210,875.1	6.2	~100.0

* Tally results represent the vegetation map layer at the map-class attribution level, without special modifiers. The bold headings within the table (above the map classes) are categories to organize the map classes. Poly, polygon; Freq, frequency; ha, hectare; Ave, average; Prct, percent; ~, about

Forest and Woodland

Map classes representing ruderal forest vegetation types account for 13.8% (4,719 polygons) of the mapped polygons and 7.6% (16,163.0 ha) of the GRSM, whereas map classes representing nonruderal forest and woodland vegetation types account for 81.8% (27,866 polygons) of the polygons but 90.0% (189,658.4 ha) of the Park. This difference indicates that nonruderal forest and woodland types are generally in larger, more homogeneous and contiguous blocks, and the average

area of a ruderal forest block is 3.4 ha compared to 6.8 ha for nonruderal forest and woodland map classes. These nonruderal forest and woodland coverage figures also discount the value of large blocks of contiguous forest that consist of numerous different nonruderal map classes.

The major component of the nonruderal forest and woodland map classes in GRSM are the Chestnut Oak / Evergreen Shrub Forest (FCES), Mixed Oak / Mixed Shrub and Herb Forest (FOHM), and Blue Ridge Hemlock - Northern Hardwood Forest (FBHH). These forests are very common throughout the Park. Together, the FCES, FOHM, and FBHH map classes cover more than 50.2% (105,843.1 ha) of the Park. In addition to covering a large area, these map classes consist of 11 vegetation types dominated by a wide range of deciduous tree species.

The ruderal forest types of GRSM are defined by only six map classes; three of the map classes are very common and three are very rare. The Ruderal Tuliptree - Walnut Forest (FXTW), Appalachian Ruderal Hardwood Forest (FXAH), and Ruderal Eastern White Pine Forest (FXWP) map classes each cover large areas of the Park in locations of historical settlement and agriculture. Usually, these ruderal forests are centered on the bottomlands and valleys of the Park, but also can include the lower forested slopes. Together these three map classes cover 7.6% (16,127.1 ha) of GRSM. The FXTW map class generally represents a monoculture or disturbed forest dominated by tuliptree (*Liriodendron tulipifera*), the FXAH map class generally represents disturbed forest dominated by a mixture of young deciduous hardwood tree species, and the FXWP map class generally represents a monoculture or disturbed forest dominated by eastern white pine (*Pinus strobus*).

Shrublands

Map classes representing ruderal shrubland vegetation types account for 0.2% (59 polygons) of the mapped polygons and 0.02% (46.5 ha) of the GRSM, whereas map classes representing nonruderal shrubland vegetation types account for 2.8% (968 polygons) of the polygons but 0.5% (1,128.3 ha) of the Park. This difference indicates that nonruderal shrubland vegetation types are generally in larger, more homogeneous and contiguous blocks, and the average area of a ruderal shrubland is 0.8 ha compared to 1.2 ha for nonruderal shrubland map classes.

The Southern Appalachian Mixed Heath Bald (SBMH) and Montane Grape Opening (SGHO) map classes are the most common shrubland map classes in the Park. These two very different map classes occur in very different locations throughout the Park. The SBMH map class only occurs on ridgetops and over thin rocky soils and slopes, whereas SGHO map class only occurs in coves over rich soils. The SBMH map class accounts for 1.9% (645 polygons) of the mapped polygons and 0.3% (691.5 ha) of the Park area, whereas SGHO accounts for 0.7% (232 polygons) of the mapped polygons and 0.2% (360.8 ha) of the Park area.

Herbaceous Vegetation

Map classes representing ruderal herbaceous vegetation types account for 0.3% (102 polygons) of the mapped polygons and 0.4% (888.8 ha) of the GRSM, whereas map classes representing nonruderal herbaceous vegetation types account for 0.1% (49 polygons) of the polygons but 0.01% (25.6 ha) of the Park. This difference indicates that ruderal herbaceous vegetation types are generally in larger,

more homogeneous and contiguous blocks, and the average area of a ruderal herbaceous vegetation is 0.3 ha compared to 0.1 ha for nonruderal herbaceous vegetation map classes.

The Cultivated Meadow (HXCM) map class accounts for almost all herbaceous vegetation found within the Park. This map class occurs almost exclusively in Cades Cove and Cataloochee where large areas of HXCM are managed for cultural and historical preservation. The HXCM map class accounts for 0.2% (74 polygons) of the mapped polygons and 0.4% (854.9 ha) of the Park area.

Cultural Vegetation

An aspect of GRSM that cannot be ignored is the cultural landscape. With the Foothills Parkway, access to Cades Cove and Cataloochee; US–441; and numerous cultural, interpretative, campgrounds and other Park infrastructure, cultural vegetation is an integral part of the Park. The cultural landscape covers 0.6% of the Park (1,277.4 ha) spread among 259 polygons.

Open Water and Unvegetated Rock

Open water in GRSM is uncommon within the Park. Overall, the Flowing and Ponded Water (NFPW) map class covers 0.8% (1,609.5 ha) of the Park; most of this area is the Fontana Lake reservoir. The Rock Slide (NRSL) map class is markedly less common than the NFPW map class and represents recent events that have left significant areas of unvegetated rock. The NRSL map class covers 0.008% (16.4 ha) of the Park and is limited to steep slopes.

Map Layer Presentation

A presentation example of the map layer produced for the GRSM vegetation mapping project is shown in Figure 12 (also provided as a stand-alone file for viewing and printing accessibility). The finest (most detail) level of the map (polygons consisting of map classes and the physiognomic cover-density modifier) is too detailed to present at a Park-wide scale; therefore, generalized map classes that were aggregated to provide a meaningful and displayable map are shown in Figure 12. These categories are the same as the bolded categories provided in Table 6.

Detailed map polygons and corresponding classification to the USNVC[11], along with supporting field data and classification to support mapping, are provided in the project geodatabase and can be accessed using GIS software. The project geodatabase is posted to the NPS Integrated Resource Management Applications Portal at the location associated with this GRSM vegetation mapping project (https://irma.nps.gov/DataStore/Reference/Profile/2165636).

[11]Each map polygon is assigned a map-class code and name and, when applicable, are linked to USNVC classification tables within the project geodatabase.

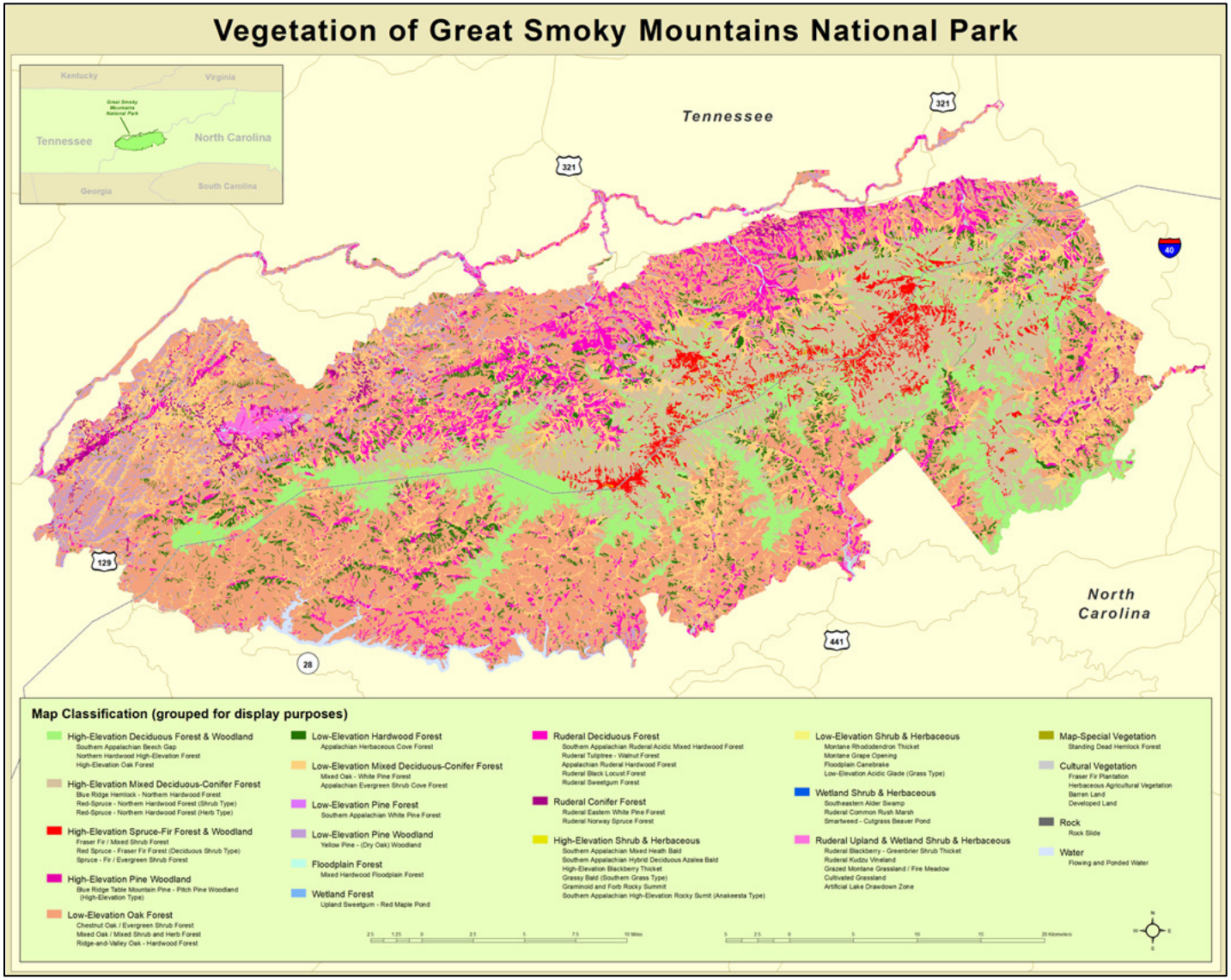

Figure 12. Vegetation map display from the Great Smoky Mountains National Park vegetation mapping project. (This figure also is provided as a stand-alone file for viewing and printing accessibility.)

Accuracy Assessment

The objective of an accuracy assessment (AA) is to measure the probability that a particular location has been assigned the correct vegetation class in the vegetation map layer. The process of an AA is based on field observations, and the process of mapping is based on aerial image interpretation; each process has different perspectives of scale and observation. An AA estimates thematic accuracy by map class in the map layer, giving users the information needed to determine suitability of the map layer for a particular application. At the same time, map layer producers are able to learn more about the nature of accuracy, including error, in the map layer. Thus, the two attributes of an AA are "users' accuracy," which is the probability that the map actually represents what was classified on the ground, and "producers' accuracy," which is the probability that an AA site has been mapped correctly. An error in mapping from the users' perspective is an error of commission where a map class was mapped as a vegetation type that did not exist at the assessment site. An error in mapping from the producers' perspective is an error of omission where a map class was not mapped as the vegetation type that existed at the assessment site. Users' and producers' accuracies can be obtained from the same set of data by using different analyses per Lea and Curtis (2010). Errors exist when map classes are not the same as the classes observed in the field. A major assumption of an AA is that the application of the classification system is identical between mapping and field assessment. When the application of classification is not applied consistently with the field assessment, a "false error" could result. A "false error" requires additional review of field data and classification decisions.

This Accuracy Assessment" section describes the AA methods that were applied to the vegetation map for the Great Smoky Mountains National Park (GRSM, also referred to as the "Park") vegetation mapping project. The section concludes by discussing the users' accuracy and producers' accuracy results, giving additional detail to map classes with lower accuracy.

Methods

An AA sampling design was developed for the GRSM vegetation mapping project. Field data were collected at AA sites that were randomly selected by the sampling design. The field data were then used to analyze the classification accuracy of the vegetation map layer.

Sampling Design

A stratified random sampling approach was used to select AA sites for the GRSM vegetation mapping project. A cost-distance layer was used to exclude areas within the administrative park boundary that were more than a 30-minute walk from a road or trail, that were on a slope greater than 45 degrees, and that were areas of severe burn from the Chimney Tops 2 fire of November 23, 2016; approximately 2,833 hectares (ha) were excluded from AA sampling because of burn severity from the Chimney Tops 2 fire. Other areas identified by Park personnel or listed as private property, also were excluded in the sampling design. All map classes representing natural (including ruderal) vegetation types in the U.S. National Vegetation Classification were included as the individual themes to randomly selected sites.

The number of samples needed for each map class (theme) was determined by using National Park Service (NPS) Vegetation Mapping Inventory (VMI) Program recommendations (Lea and Curtis 2010) as suggested in the following scenarios.

- Scenario A—The class is abundant, covering more than 50 ha. The map class receives the maximum sample size of 30.
- Scenario B—The class is relatively abundant, covering at least 8.33 ha, but no more than 50 ha. The map class receives a sample size of six-tenths of the observations per hectare of the map class (equal to one observation for every 1.67 ha of map-class area). (This ratio allocates observations at a density rate equal to 30 observations per 50 ha).
- Scenario C—The class is relatively rare, covering less than 8.33 ha. The map class receives five observations, which is the recommended minimum sample size.

For Scenario C, a class could receive less than five observations if the area was on private land or if the total area was extremely low.

A random selection of AA site locations was buffered from the polygon boundaries in the vegetation map layer to ensure that field classification of the observed area (a circular area about the size of the minimum mapping unit [MMU]) for each AA site would not overlap with vegetation types represented in adjacent polygons.

The required buffer distance was calculated with the following formula:

$$\text{Buffer Distance} = \sqrt{R^2 + F^2 + M^2}$$

where

R is the radius distance of the observation area,

F is the expected (e.g., 90th percentile) global positioning system (GPS) error distance, and

M is the standard requirement (maximum positional error distance in the map) for positional accuracy.

The MMUs that were used to map GRSM were 0.5 and 0.25 ha, depending on the map class; map-class MMUs are described in the "Vegetation Mapping" section of this report. Depending on MMU size, values vary for R, F, M, and the polygon buffer distance; these values are given in Table 7. The value of R is 40 meters for 0.5 ha and 28 meters for 0.25 ha. The values of F and M are generalized to 15 and 12 meters, respectively. Therefore, a buffer distance of either 44 meters for a 0.5-ha MMU map class or 34 meters for a 0.25-ha MMU map class was applied to the interior side of polygon boundaries.

As described in the "Vegetation Mapping" section of this report, the Park was mapped one State at a time, and AA data were collected during three field seasons. Sites selected for the North Carolina side during the first field season were derived from interpolated estimates of the total hectares per map class throughout the Park. An identical number of sites were selected for the Tennessee side

during the second field season. For example, if a map class was estimated to be greater than 50 ha, 12 sites were selected for the first field season (the North Carolina side) and 12 sites were selected for the second field season (the Tennessee side) for that map class. During the third and final field season, six sites were randomly distributed throughout the Park to bring the number of AA sites for the map class to 30 and ensure a balanced random sampling.

Table 7. Values for calculating buffer distance from map polygon boundaries for the random selection of accuracy assessment sites.*

MMU (ha)	R (m)	F (m)	M (m)	Buffer (m)
0.5	40	15	12	44
0.25	28	15	12	34

* MMU, minimum mapping unit; ha, hectare; R, radius; m, meter; F, global positioning system error; M, map positional accuracy

Once the number of AA sites was determined and buffers were applied, random sites with associated geographic coordinates were generated for each map class using the Geospatial Modelling Environment suite of tools (Spatial Ecology LLC) for the first field season. For the remaining two field seasons, sites were located by using the Mapped and Attributed Data Random Area and Point (MADRAP) Generator (Harrison et al. 2019). A different tool was used in the second and third field seasons because of changes in software platform that prohibited the use of the Geospatial Modelling Environment suite of tools. The site coordinates were projected in the Universal Transverse Mercator coordinate system, Zone 17 North, by using the North American Datum of 1983. The site coordinates along with the MMU for each site and an accompanying survey area boundary (if different than a circle) were provided to AA field teams (field crews) electronically. Field crews uploaded the coordinates to the GPS receivers that were used in the field.

Field Data Collection

Without knowing the map classifications of AA site locations, field observation data were collected by field crews that consisted of different individuals; each field crew consisted of a lead botanist and field assistant who were trained in AA procedures by ecologists from NatureServe and the U.S. Geological Survey Upper Midwest Environmental Sciences Center (UMESC). Each field crew navigated to the preselected AA sites using GPS.

For each AA site, a field crew assessed an area about the size of the MMU. The size of the MMU defined for each AA site either is a circle with a 40-meter radius for an MMU of 0.5 ha; a circle with a 28-meter radius for an MMU of 0.25 ha; or if the mapped polygon boundaries could not support a circular MMU, an area specified by polygon boundaries that was provided. At each AA site, a field crew determined the assessment area size (0.5 or 0.25 ha) by looking at the colored symbol of the AA site or looking at the attribution of the sites. When the AA survey site was a shape other than a circle, the shape was provided to the field crew via GPS, and the area represented by the polygon was surveyed by the filed crew.

Within the targeted assessment area, the field crew recorded data that included the GPS coordinate location, dominant species and any indicator species noted in the field key, environmental data, pertinent comments, and a series of systematic photographs. The indicator species noted in the field key are drawn from the full USNVC association description. These indicator species aided a field crew in keying to the correct association at an AA site. Plant taxonomy and nomenclature were recorded per Weakley (2015). Data were entered digitally onsite using the Survey 123 platform (Esri, version 3.6). This process reduced the risk of missing data fields (which could be set to mandatory) and data entry errors (with predefined options for fields) into the PLOTS (National Park Service 2015) database. Figure 13 shows a screenshot of the digital AA form and a field crew member using the form and a field key to identify vegetation types of GRSM (draft version from 2017). When the vegetation type was uncertain (e.g., a vegetation type that expressed a variation not supported by the vegetation field key or an ecotone between two vegetation types), the crew still made a single "best call" but took extra notes on the circumstance. In other instances, an "alternate field call" was recorded, thus providing a second vegetation type to classify a specific site. When two vegetation types were recognized, the crew was instructed to note the vegetation type that contained the most area within the radius of an MMU. For additional field collection details and procedures, see "Appendix C: Accuracy Assessment Field Manual."

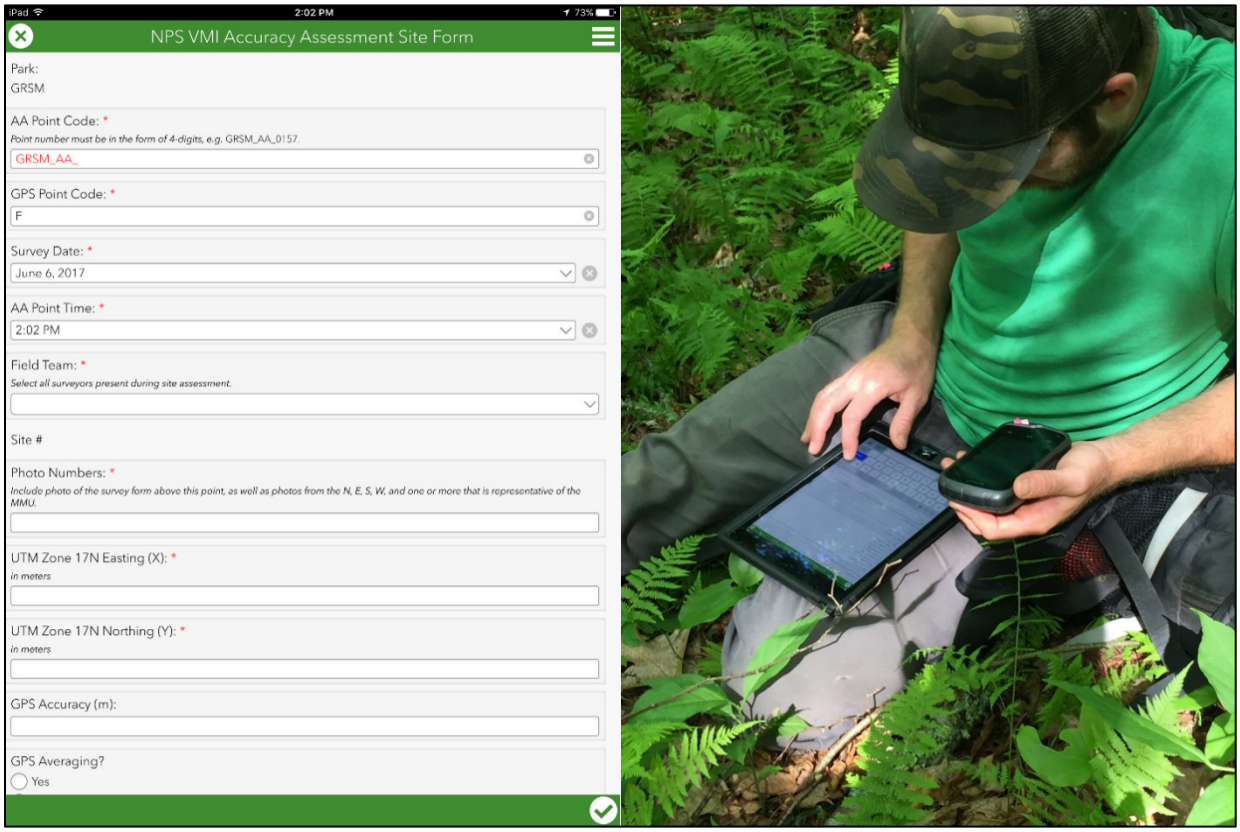

Figure 13. The left one-half shows the digital accuracy assessment form using the Survey 123 platform. The right one-half shows field classification data entry of an accuracy assessment site for the Great Smoky Mountains National Park Vegetation mapping project.

Field Data Review

Following the collection of field data, a systemic review and update were completed on each AA site prior to analysis. The survey elevation for each site was updated using Light Detection and Ranging (LiDAR) data layer of GRSM with the survey GPS location used to determine the elevation from the LiDAR layer. Park staff then reviewed the data for each AA site to ensure completeness of data and to ensure that the plant species list for each site contained species that were known to occur in the Park and were appropriate to the location of the AA site. Finally, the field call(s) for each site was reviewed with a final "office" call provided by the project ecologist. This office call, based on all the data and photographs collected for the AA site, became the official vegetation classification for the AA site that was then used in the final analysis.

Data Analyses

Field data for 972 AA sites were collected (341 in 2017, 376 in 2018, and 255 in 2019) and then imported into the NPS PLOTS version 4.0 (National Park Service 2015) database for the project, with subsequent review of data entry. Locations of these 972 AA sites are shown in Figure 14. Of the 972 AA collection sites, 2 sites were excluded from the analysis because of unresolvable issues with the field data, and another 4 sites were excluded because the sites were in a severe burn area missed by the cost-distance surface analysis. Thus, 966 AA sites were used in the analysis of vegetation map layer accuracy. The analysis included the following steps:

- initial comparative analysis of the field-site and map-polygon data,
- review of all disagreements and correction of false errors as necessary,
- analysis of individual map classes,
- final output of results into a contingency (matrix) table, and
- final output of the analyses and results into a spatial database for use in a geographic information system (GIS).

Initial Comparative Analysis

The AA field-site data and map-polygon data were spatially joined using ArcGIS (Version 10.7, Esri). Each AA field-site classification call (to a vegetation type) was compared to the corresponding map-polygon classification call (to a map class representing one or more vegetation types). Results from this initial comparison were tabulated either as a "match" (agreement) or a "mismatch" (disagreement). Matches were determined when either the primary or the secondary field-site calls were in agreement with the map-polygon call. Mismatches were determined when the criteria for a match were not met. The initial comparison revealed that 64.10% of the AA sites matched the corresponding mapped polygons.

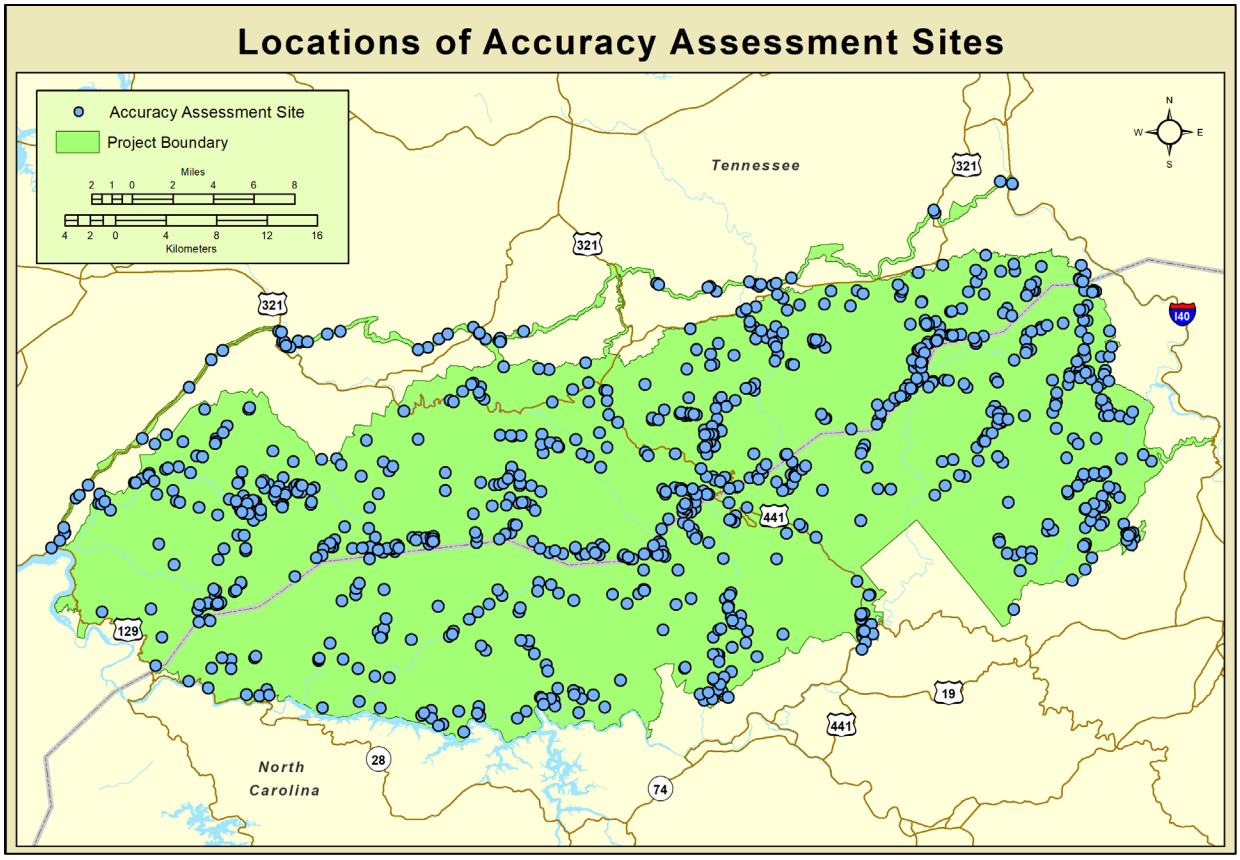

Figure 14. Locations of accuracy assessment sites to assess the accuracy of the vegetation map layer for the Great Smoky Mountains National Park vegetation mapping project.

Review of Disagreements

Each set of mismatched classification calls were reviewed to ascertain as being a "false error" or a "true error." A false error is defined as a mismatch that was caused by one of the following: (1) a spatial accuracy error in the field-site coordinates or map layer, (2) a missing or misapplied field-site classification call, (3) a field-site assessment of an area smaller than an MMU for the map class being assessed (an inclusion), or (4) a significant change in vegetation with time (i.e. between image acquisition and AA sampling). In contrast, a true error is defined as a mismatch that was caused by the mapping, determined after investigating causes for a false error. This review process involved using ArcGIS to locate and view the AA field-site locations and the corresponding polygons on a computer screen by using digital aerial imagery and the software program "Stereo Analyst for ArcGIS" (ERDAS, Inc.). The field data sheets also were reviewed to gain a fuller sense of the context of the ground data. A classification determined to be a false error could be reclassified as a match pending a secondary review during an AA reconciliation meeting.

Spatial Accuracy

A spatial error might exist when (1) the GPS device acquired inaccurate field coordinates or (2) a geospatial error existed within the vegetation map layer (called a "map-layer shift"). These spatial errors could displace the newly acquired field coordinate to an adjacent polygon on the map layer.

Spatial errors in GPS coordinates were minimized during the random site selection process by selecting AA site coordinates more than 34 meters (for 0.25-ha MMU map classes) or more than 44 meters (for 0.5-ha MMU map classes) from map polygon edges; however, field-acquired GPS coordinates collected with a poor GPS accuracy could position the coordinates into an adjacent map polygon. Furthermore, during AA site selection, the buffer distance from polygon edges was reduced when the target number of AA sites for a map class could not otherwise be attained; this increased the likelihood that the field-acquired GPS position was not in the correct map polygon, even with acceptable GPS accuracy.

Questionable Field-Site Classification Call

A field-site classification call might be questioned during the analysis. A likely reason for questioning a field-site call was when the perspective from the ground was limited by impenetrable vegetation, or wet soils preventing the field crew from accessing the AA site; i.e., the area of an MMU for the map class being assessed. Another reason for questioning a field-site call was if the AA site was diverse, and other vegetation types were omitted or not recognized by the field crew. Questionable field-site calls were reviewed by checking the aerial imagery and by inspecting the field data sheets for misapplications. Questionable field-site calls required further, joint analysis by UMESC, NatureServe, and GRSM staff during the AA reconciliation meeting.

Inclusion

The actual area assessed in the field might have been less than the area of an MMU for the map class being assessed; therefore, the assessed area was termed an inclusion. The AA site in question may have contained vegetation that was merely an inclusion (smaller than an MMU for the map class being assessed) to the AA site area. Certain vegetation features are quite distinct from each other when the aerial imagery was viewed three-dimensionally (e.g., open woodland or dense forest), which makes for easy determination of site inclusion. An inclusion also might exist when the field assessment was indeed of a proper area (of an MMU for the map class being assessed), but the field-assessed area overlapped into an adjacent map polygon. Determining if the assessed area actually falls within the intended polygon can sometimes be difficult, particularly in the case of smaller map polygons. Along with the questionable field-site classification calls, inclusion errors required further joint analysis by UMESC, NatureServe, and GRSM staff during the AA reconciliation meeting.

Vegetation Change with Time

The vegetation map layer represents the ground conditions as presented in the aerial imagery that was acquired for the GRSM vegetation mapping project. Sometimes the vegetation landscape changed between the date of imagery and the date of AA field assessment, which was a range between 2 and 4 years. When this change happened, the assessed area was termed as a change in vegetation with time. Determinations of vegetation change were easily made by a comparison between the aerial imagery and AA field-site pictures. Examples of changes in the vegetation landscape are tree mortality from insect infestation or maintenance activities by the Park. Determinations were confirmed during the AA reconciliation meeting.

Individual Map-Class Analysis

A contingency table was generated to present the results of the initial analysis of the AA data with the vegetation map layer. This contingency table provided information including users' and producers' accuracies of individual map classes and agreements and disagreements of map classes. Individual map-class accuracies that fell below the NPS VMI Program standard were reviewed to determine which map classes were in confusion with each other. If repeated confusion was evident, a decision was made whether to merge the map classes to gain higher accuracy or to leave the map classes separate and accept lower accuracy. When a lower accuracy was accepted, the benefits of having that particular class mapped separately outweighed the benefits of a merge with other classes to produce a higher accuracy. These decisions were made with input from UMESC and GRSM staff.

To avoid underestimating the role that the NPS, NatureServe, and UMESC staff played in the reconciliation of AA results and the effect that these results had on the final map classification for GRSM, further understanding is needed of the processes and steps that ultimately produced the final AA results and map classification. The following is an outline of the discussions among GRSM, NatureServe, and UMESC staff regarding AA issues, AA results, and eventual merging of map classes.

Review and Reconciliation of Site-Specific AA Field Data

Staff from NatureServe, UMESC, and GRSM met to review and reconcile site-specific AA field data. This meeting took place at the UMESC during January 28–30, 2020. Site-specific AA field data were reviewed for potential changes to classification assignments, for inclusions of vegetation not characterized by the MMU, and for vegetation that changed from the time of imagery capture to the time of AA data collection. Adjustments to the vegetation classification, mapping classification, and field key to vegetation types also were addressed. Of the 972 analyzed AA sites, 203 were included in the review and reconciliation of AA field data.

Postreconciliation AA Contingency Table

The AA contingency table was updated to reflect adjustments from the review and reconciliation meeting. Individual map classes that fell below the 80% accuracy standard of the NPS VMI Program were studied for where confusion was present in the mapping. Detailed proposals were drafted, and the proposals listed the potential merges of map classes that had consistent confusion in mapping. These proposals were sent to GRSM staff for input and decision. Each proposed resolution explained the pros and cons regarding the resolution's effect on the vegetation map layer. This information helped GRSM staff to realize the cost-benefit ratio of accepting a map class with lower than standard accuracy to retain map detail or of accepting a merging of map classes to gain higher accuracy but lose some map detail. These proposals and the associated NPS decisions are outlined in "Appendix D: Accuracy Assessment Reconciliation."

Final AA Contingency Table

The results from the complete analyses, including the reconciliations of AA site data and the consolidation of map classes, were updated into the contingency table. The frequency of agreement and the placement of disagreements are listed in the contingency table. The percentages of users' and producers' accuracies were recalculated for each map class.

AA Spatial Database

For use in a GIS, a feature-class layer and supporting tables were produced of the AA site locations; the layer and tables were incorporated into the geodatabase for the GRSM vegetation mapping project. The field data for AA also are included in the NPS PLOTS version 4.0 (National Park Service 2015) database for the project. These datasets are posted to the NPS Integrated Resource Management Applications (IRMA) Portal at the location associated with this GRSM vegetation mapping project (https://irma.nps.gov/DataStore/Reference/Profile/2165636).

Results and Discussion

Of the 966 sites used in the analysis, the initial comparison determined that only 64.10% of the AA sites matched the corresponding polygons that represented natural (including ruderal) vegetation types. Through the review process of correcting false errors and of combining some map classes because of low accuracies, the overall accuracy was increased to 84.64 %. A kappa adjustment for chance agreements resulted in an overall accuracy of 79.96%.

The contingency matrix of the AA results can be accessed from the NPS IRMA Portal at the location associated with this project. The matrix table lists the accuracy of each map class (along with 90% confidence intervals); with the users' accuracy reflecting errors of inclusion (commission errors) and the producers' accuracy reflecting errors of exclusion (omission errors). The width of each confidence interval was affected by the sample size used to derive the point estimate.

The overall AA met the accuracy requirement of 80% established by the NPS VMI Program. The most important factors affecting accuracy were (1) confusion of oak forest types, (2) percent cover of conifer versus hardwood, (3) confusion among different ruderal forest classes, (4) confusion between similar ruderal and nonruderal forests (Southern Appalachian Ruderal Acidic Mixed Hardwood Forest [FXSH] and Chestnut Oak / Evergreen Shrub Forest [FCES], Ruderal Eastern White Pine Forest [FXWP] and Appalachian Evergreen Shrub Cove Forest [FAEC]), and (5) misestimation of percent canopy cover. In regard to percent-cover estimates, past experience indicates that estimates in the field are generally lower than estimates from an aerial survey; thus, some mismatches were from a result of two different perspectives.

With the analysis complete, some individual map-class accuracies did not meet the 80% requirement (taking into account 90% confidence intervals). Generally, errors of commission (users' accuracy) occurred in fewer map classes than did errors of omission (producers' accuracy). The following are map classes for which the mapping project did not meet the required rates of accuracy in terms of the actual percentage or the confidence intervals.

Users' Accuracy (Errors of Commission)

For each map class that has a users' accuracy (errors of commission) below NPS VMI Program standards, the individual errors of commission are reviewed and reported. This section presents the individual map classes with users' accuracy below program standards and the associated map classes with which the errors of commission occur. A low users' accuracy indicates that a map class was mapped too aggressively, which refers to an overapplication of the map class within the Park. At the individual AA site level, the low users' accuracy indicates that for the map class being tested, AA

determined that the vegetation at the AA site is represented by a different map class (e.g., the mappers called the polygon the FXSH map class, but the AA recognized a vegetation type at the AA site that is represented by the FCES map class).

For simplification, the following explanations of map classes with low-users' accuracy provide vegetation classification of AA sites using map classes that represent the classified vegetation types. Some map classes represent multiple vegetation types. For the purpose of these explanations, the level of detail by vegetation type is not necessarily needed.

Southern Appalachian Ruderal Acidic Mixed Hardwood Forest (FXSH) Map Class

The users' accuracy for the Southern Appalachian Ruderal Acidic Mixed Hardwood Forest (FXSH) map class was 63%, with a 90% confidence interval of 47–79%. Of the 30 AA sites tested for FXSH, 11 sites contained vegetation types other than FXSH. The following are the attributed errors.

- Ten Chestnut Oak / Evergreen Shrub Forest (FCES) sites and one Appalachian Ruderal Hardwood Forest (FXAH) site were mapped as FXSH because mappers underestimated the coverage of chestnut oak (*Quercus montana*) and underestimated the degree of disturbance to a ruderal, mixed-hardwood site.

Blue Ridge Hemlock - Northern Hardwood Forest (FBHH) Map Class

The users' accuracy for the Blue Ridge Hemlock - Northern Hardwood (FBHH) map class was 60%, with a 90% confidence interval of 44–76%. Of the 30 AA sites tested for FBHH, 12 sites contained vegetation types other than FBHH. The following is a list of attributed errors.

- One FXSH site was mapped as FBHH because the degree of disturbance was underestimated.
- One Northern Hardwood High-Elevation Forest (FNHH) site was mapped as FBHH because evergreen shrub cover was overestimated.
- Two FCES sites and one High-Elevation Oak Forest (FHEO) were mapped as FBHH because oak species (*Quercus* spp.) canopy cover was underestimated.
- One Appalachian Herbaceous Cove Forest (FAHC) site was mapped as FBHH because rich herb cover was misinterpreted as evergreen shrub cover, and tuliptree (*Liriodendron tulipifera*) cover was underestimated.
- Three Red Spruce - Northern Hardwood Forest (Shrub Type) (FSHE) sites and three Red Spruce - Northern Hardwood Forest (Herb Type) (FSHH) sites were mapped as FBHH because of the underestimation of red spruce (*Picea rubens*) in the canopy.

Appalachian Evergreen Shrub Cove Forest (FAEC) Map Class

The users' accuracy for the Appalachian Evergreen Shrub Cove Forest (FAEC) map class was 63%, with a 90% confidence interval of 50–77%. Of the 41 AA sites tested for FAEC, 15 sites contained vegetation types other than FAEC. The following is a list of attributed errors.

- Four Ruderal Eastern White Pine Forest (FXWP) sites were mapped as FAEC because mappers underestimated the degree of disturbance to the system and underestimated coverage of eastern white pine (*Pinus strobus*).

- Two Ruderal Tuliptree - Walnut Forest (FXTW) sites were mapped as FAEC because mappers underestimated the degree of disturbance to the system.
- Three FXAH sites were mapped as FAEC because mappers underestimated the degree of disturbance to the system and were unable to distinguish the shrub layer.
- Three Mixed Oak / Mixed Shrub and Herb Forest (FOHM) sites and one FCES site were mapped as FAEC because mappers underestimated the cover of oaks.
- One FAHC site was mapped as FAEC because mappers overestimated the amount of evergreen shrub.
- One Mixed Hardwood Floodplain Forest (FFMH) site was mapped as FAEC because mappers underestimated the width of the floodplain.

Appalachian Ruderal Hardwood (FXAH) Map Class

The users' accuracy for the Appalachian Ruderal Hardwood (FXAH) map class was 60%, with a 90% confidence interval of 44–76%. Of the 30 AA sites tested for FXAH, 12 sites contained vegetation types other than FXAH. The following is a list of attributed errors.

- Five FXTW sites were mapped as FXAH because mappers underestimated the coverage of tuliptree.
- One Ruderal Sweetgum Forest (FXSG) site was mapped as FXAH because mappers underestimated the coverage of sweetgum (*Liquidambar styraciflua*).
- Four FOHM sites and one FCES site were mapped as FXAH because mappers underestimated the cover of oak species in the canopy.
- One FAHC site was mapped as FXAH because mappers overestimated the degree of disturbance to the canopy.

Ruderal Eastern White Pine Forest (FXWP) Map Class

The users' accuracy for the Ruderal Eastern White Pine Forest (FXWP) map class was 60%, with a 90% confidence interval of 44–76%. Of the 30 AA sites tested for FXWP, 12 sites contained vegetation types other than FXWP. The following is a list of attributed errors.

- Six FAEC sites were mapped as FXWP because mappers overestimated the coverage of eastern white pine and overestimated the degree of disturbance.
- One Yellow Pine - (Dry Oak) Woodland (WYPO) site was mapped as FXWP because mappers underestimated the cover of shortleaf pine (*Pinus echinata*).
- One Southern Appalachian White Pine Forest (FAWP) site was mapped as FXWP because mappers overestimated the degree of disturbance.
- Two FXTW sites and one FXAH site were mapped as FXWP because mappers overestimated the coverage of eastern white pine.
- One Mixed Oak - White Pine Forest (FOWP) site was mapped as FXWP because mappers overestimated eastern white pine coverage and overestimated the degree of disturbance.

Producers' Accuracy (Errors of Omission)

For map classes that have a producers' accuracy (errors of omission) below programmatic standards, each map class and the individual errors of omission are reviewed. A low producers' accuracy indicates that a map class was mapped too conservatively, which refers to an underapplication of the map class within the Park. This section presents the individual map classes with low producers' accuracy and the associated map classes with which the errors of omission occur. At the individual AA site level, therefore, the AA determined that the vegetation at the AA site was the map class being reviewed, but that the mappers called the polygon in which the AA site is located within a different map class (e.g. the AA recognized a vegetation type at the AA site that is represented by FCES, but the mappers called the polygon FXSH).

For the same reasons given for the explanations of map classes with low users' accuracy, the following explanations are provided of map classes with low-producers' accuracy. These explanations provide vegetation classification of AA sites by using the map classes that represent the classified vegetation types.

Chestnut Oak / Evergreen Shrub Forest (FCES) Map Class

The producers' accuracy for the Chestnut Oak / Evergreen Shrub Forest (FCES) map class was 47%, with a 90% confidence interval of 34–60%. Of the 49 AA sites classified in the field as FCES, 26 sites fell within polygons that were mapped as other vegetation types. The following is a list of attributed errors.

- Ten sites assessed in polygons mapped as FXSH were determined to be FCES. Mappers underestimated the amount of oak cover in the canopy.
- Six sites assessed in polygons mapped as FOHM were determined to be FCES. Mappers underestimated the amount of evergreen or deciduous heath shrub cover.
- Two sites assessed in polygons mapped as FBHH were determined to be FCES. Mappers underestimated the amount of chestnut oak in the canopy.
- Two sites assessed in polygons mapped as FOWP were determined to be FCES. Mappers overestimated the amount of eastern white pine in the canopy.
- One site assessed in polygons mapped as FAWP was determined to be FCES. Mappers overestimated the amount of eastern white pine in the canopy.
- One site assessed in polygons mapped as FAEC was determined to be FCES. Mappers underestimated the total amount of oak canopy present.
- One site assessed in polygons mapped as FXAH was determined to be FCES. Mappers underestimated the total amount of oak canopy present and overestimated the amount of disturbance present.
- Two sites assessed in polygons mapped as Ruderal Blackberry - Greenbrier Shrub Thicket (SXBG) were determined to be FCES. Mappers underestimated the total amount of oak canopy present and overestimated the amount of disturbance present.
- One site assessed in polygons mapped as Southern Appalachian Mixed Heath Bald (SBMH) was determined to be FCES. Mappers underestimated the total amount of oak canopy present.

Red Spruce - Northern Hardwood Forest (Herb Type) (FSHH) Map Class

The producers' accuracy for the Red Spruce - Northern Hardwood Forest (Herb Type) (FSHH) map class was 60%, with a 90% confidence interval of 47–73%. Of the 45 AA sites classified in the field as FSHH, 18 sites fell within polygons that were mapped as other vegetation types. The following is a list of attributed errors.

- Five sites assessed in polygons mapped as Red Spruce - Fraser Fir Forest (Deciduous Shrub Type) (FSFD) were determined to be FSHH. Mappers overestimated the canopy cover of red spruce.
- Four sites assessed in polygons mapped as Red Spruce - Northern Hardwood Forest (Shrub Type) (FSHE) were determined to be FSHH. Mappers overestimated the amount of evergreen shrub present.
- Three sites assessed in polygons mapped as FBHH were determined to be FSHH. Mappers underestimated the canopy cover of red spruce and underestimated the amount of evergreen shrub present.
- Three sites assessed in polygons mapped as FNHH were determined to be FSHH. Mappers underestimated the canopy cover of red spruce.
- Two sites assessed in polygons mapped as Fraser Fir / Mixed Shrub Forest (FFFS) were determined to be FSHH. Mappers misidentified Fraser fir as red spruce and overestimated total conifer canopy cover.
- One site assessed in polygons mapped as High-Elevation Blackberry Thicket (SHBT) was determined to be FSHH. Mappers underestimated total tree canopy cover.

Appalachian Ruderal Hardwood Forest (FXAH) Map Class

The producers' accuracy for the Appalachian Ruderal Hardwood Forest (FXAH) map class was 55%, with a 90% confidence interval of 39–70%. Of the 33 AA sites classified in the field as FXAH, 15 sites fell within polygons that were mapped as other vegetation types. The following is a list of attributed errors.

- Four sites assessed in polygons mapped as FXTW were determined to be FXAH. Mappers overestimated the canopy cover of tuliptree.
- Three sites assessed in polygons mapped as FAEC were determined to be FXAH. Mappers underestimated the degree of disturbance and overestimated the amount of evergreen shrub.
- Three sites assessed in polygons mapped as FXSG were determined to be FXAH. Mappers overestimated the canopy cover of sweetgum.
- Two sites assessed in polygons mapped as Montane Rhododendron Thicket (SMRT) were determined to be FXAH. Mappers underestimated the total amount of tree canopy and amount of disturbance.
- One site assessed in polygons mapped as FXSH was determined to be FXAH. Mappers underestimated the amount of disturbance.

- One site assessed in polygons mapped as FXWP was determined to be FXAH. Mappers overestimated the canopy cover of eastern white pine.
- One site assessed in polygons mapped as WYPO was determined to be FXAH. Mappers overestimated the canopy cover of yellow pine.

Ruderal Tuliptree - Walnut Forest (FXTW) Map Class

The producers' accuracy for the Ruderal Tuliptree - Walnut Forest (FXTW) map class was 59%, with a 90% confidence interval of 45–73%. Of the 39 AA sites classified in the field as FXTW, 16 sites fell within polygons that were mapped as other vegetation types. The following is a list of attributed errors.

- Five sites assessed in polygons mapped as FXAH were determined to be FXTW. Mappers underestimated the canopy cover of tuliptree.
- Two sites assessed in polygons mapped as FAEC were determined to be FXTW. Mappers underestimated the degree of disturbance and overestimated the amount of evergreen shrub.
- Two sites assessed in polygons mapped as FOHM were determined to be FXTW. Mappers overestimated the canopy cover of oaks and underestimated the degree of disturbance.
- Two sites assessed in polygons mapped as FXWP were determined to be FXTW. Mappers overestimated the canopy cover of eastern white pine.
- One site assessed in polygons mapped as FAHC was determined to be FXTW. Mappers underestimated the degree of disturbance.
- One site assessed in polygons mapped as FFMH was determined to be FXTW. Mappers underestimated the degree of disturbance and overestimated the influence of the floodplain.
- One site assessed in polygons mapped as Ridge-and-Valley Oak - Hardwood Forest (FROH) was determined to be FXTW. Mappers overestimated the canopy cover of oaks and underestimated the degree of disturbance.
- One site assessed in polygons mapped as FXSG was determined to be FXTW. Mappers overestimated the amount of sweetgum in the canopy.
- One site assessed in polygons mapped as SXBG was determined to be FXTW. Mappers underestimated the total tree canopy cover.

Concluding Discussion

Recognizing the causes of the errors within this map is important for the map to be a successful resource management tool. By reviewing what is known about sample size and errors and the cause of the errors, the strengths and weaknesses of the map become apparent. This information allows the user to determine how reliable the map data are in respect to any map class or management decision. Additionally, the information provides insight into how the frequency of a map class can affect the accuracy of a map class.

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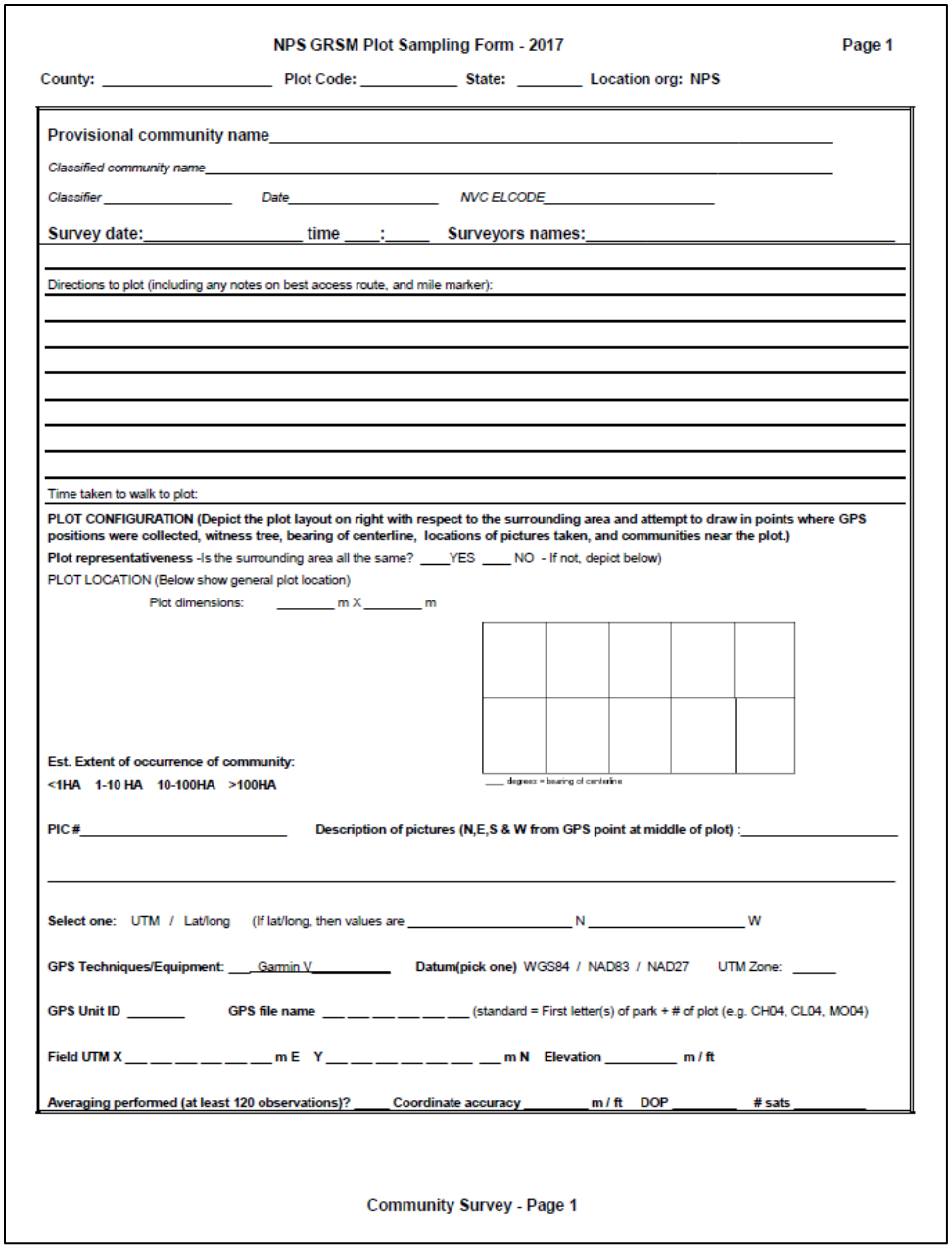
Appendix A: Field Forms

Graphics of field forms are presented in Figures A-1 through A-5.



NPS GRSM Plot Sampling Form - 2017 Page 1

County: _____ Plot Code: _____ State: _____ Location org: NPS

Provisional community name_____

*Classified community name*_____

*Classifier*_____ *Date*_____ *NVC ELCODE*_____

Survey date:_____ time ____:_____ Surveyors names:_____

Directions to plot (including any notes on best access route, and mile marker):

Time taken to walk to plot:

PLOT CONFIGURATION (Depict the plot layout on right with respect to the surrounding area and attempt to draw in points where GPS positions were collected, witness tree, bearing of centerline, locations of pictures taken, and communities near the plot.)

Plot representativeness -Is the surrounding area all the same? ____YES ____ NO - If not, depict below)

PLOT LOCATION (Below show general plot location)

Plot dimensions: _____ m X _____ m

___ degrees = bearing of centerline

Est. Extent of occurrence of community:

<1HA 1-10 HA 10-100HA >100HA

PIC #_____ **Description of pictures (N,E,S & W from GPS point at middle of plot) :**_____

Select one: UTM / Lat/long (If lat/long, then values are _____ N _____ W

GPS Techniques/Equipment: ___Garmin V_____ **Datum(pick one)** WGS84 / NAD83 / NAD27 UTM Zone: _____

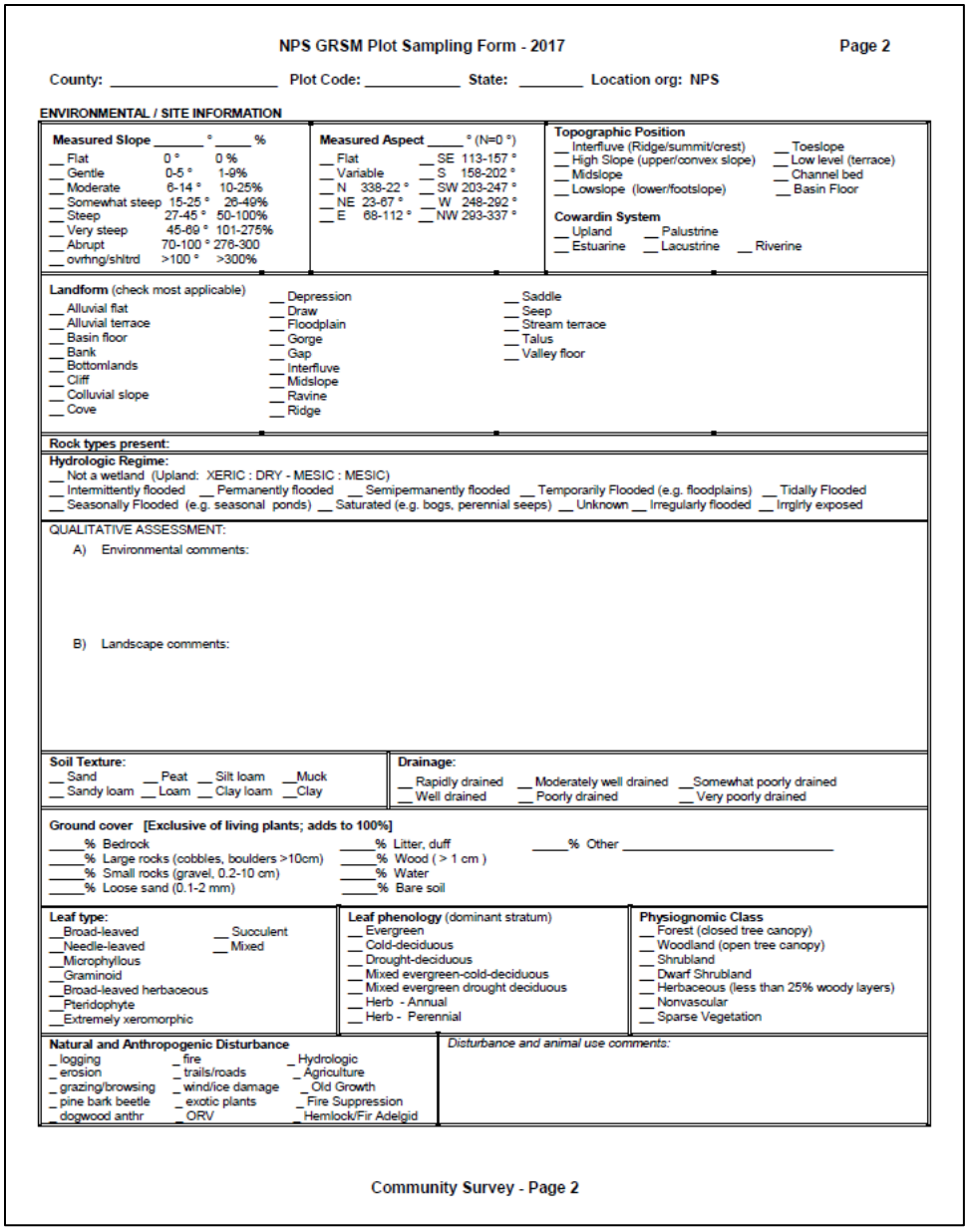
GPS Unit ID _____ **GPS file name** ___ ___ ___ ___ ___ ___ (standard = First letter(s) of park + # of plot (e.g. CH04, CL04, MO04)

Field UTM X ___ ___ ___ ___ ___ ___ **m E** **Y** ___ ___ ___ ___ ___ ___ ___ **m N** **Elevation** _____ **m / ft**

Averaging performed (at least 120 observations)? _____ **Coordinate accuracy** _____ **m / ft** **DOP** _____ **# sats** _____

Community Survey - Page 1

Figure A-1a. Graphical example of the first page of a hard-copy data form titled “NPS GRSM Plot Sampling Form - 2017” that was used to survey vegetation community plots for the Great Smoky Mountains National Park vegetation mapping project. This page of the form was used to collect data on the following: county, plot code, state, location organization, provisional community name, classified community name, classifier, date, National Vegetation Classification (NVC) Elcode, survey date, survey time, surveyors names, directions to plot, time taken to walk to plot, plot configuration, plot representativeness, plot location, plot dimensions, estimated extent of occurrence of community, pictures, description of pictures including four cardinal directions and middle of plot, global positioning system (GPS) coordinate system, GPS techniques or equipment, GPS datum, GPS unit identification, GPS file name, GPS field Universal Transverse Mercator (UTM) coordinates X easting and Y northing, GPS elevation, GPS averaging, GPS coordinate accuracy, GPS dilution of precision (DOP), and number of GPS satellites.



NPS GRSM Plot Sampling Form - 2017 Page 2

County: _____ Plot Code: _____ State: _____ Location org: NPS

ENVIRONMENTAL / SITE INFORMATION

Measured Slope _____ ° _____ %

__ Flat	0 °	0 %
__ Gentle	0-5 °	1-9%
__ Moderate	6-14 °	10-25%
__ Somewhat steep	15-25 °	26-49%
__ Steep	27-45 °	50-100%
__ Very steep	45-69 °	101-275%
__ Abrupt	70-100 °	276-300
__ ovrhng/shltrd	>100 °	>300%

Measured Aspect _____ ° (N=0 °)

__ Flat		__ SE	113-157 °
__ Variable		__ S	158-202 °
__ N	338-22 °	__ SW	203-247 °
__ NE	23-67 °	__ W	248-292 °
__ E	68-112 °	__ NW	293-337 °

Topographic Position

__ Interfluve (Ridge/summit/crest) __ Toeslope
__ High Slope (upper/convex slope) __ Low level (terrace)
__ Midslope __ Channel bed
__ Lowslope (lower/footslope) __ Basin Floor

Cowardin System

__ Upland __ Palustrine
__ Estuarine __ Lacustrine __ Riverine

Landform (check most applicable)

__ Alluvial flat
__ Alluvial terrace
__ Basin floor
__ Bank
__ Bottomlands
__ Cliff
__ Colluvial slope
__ Cove
__ Depression
__ Draw
__ Floodplain
__ Gorge
__ Gap
__ Interfluve
__ Midslope
__ Ravine
__ Ridge
__ Saddle
__ Seep
__ Stream terrace
__ Talus
__ Valley floor

Rock types present:

Hydrologic Regime:

__ Not a wetland (Upland: XERIC : DRY - MESIC : MESIC)
__ Intermittently flooded __ Permanently flooded __ Semipermanently flooded __ Temporarily Flooded (e.g. floodplains) __ Tidally Flooded
__ Seasonally Flooded (e.g. seasonal ponds) __ Saturated (e.g. bogs, perennial seeps) __ Unknown __ Irregularly flooded __ Irrglrly exposed

QUALITATIVE ASSESSMENT:

A) Environmental comments:

B) Landscape comments:

Soil Texture:

__ Sand __ Peat __ Silt loam __Muck
__ Sandy loam __ Loam __ Clay loam __Clay

Drainage:

__ Rapidly drained __ Moderately well drained __Somewhat poorly drained
__ Well drained __ Poorly drained __ Very poorly drained

Ground cover [Exclusive of living plants; adds to 100%]

_____% Bedrock
_____% Large rocks (cobbles, boulders >10cm)
_____% Small rocks (gravel, 0.2-10 cm)
_____% Loose sand (0.1-2 mm)
_____% Litter, duff
_____% Wood (> 1 cm)
_____% Water
_____% Bare soil
_____% Other _____

Leaf type:

__Broad-leaved __ Suoculent
__Needle-leaved __ Mixed
__Microphyllous
__Graminoid
__Broad-leaved herbaceous
__Pteridophyte
__Extremely xeromorphic

Leaf phenology (dominant stratum)

__ Evergreen
__ Cold-deciduous
__ Drought-deciduous
__ Mixed evergreen-cold-deciduous
__ Mixed evergreen drought deciduous
__ Herb - Annual
__ Herb - Perennial

Physiognomic Class

__ Forest (closed tree canopy)
__ Woodland (open tree canopy)
__ Shrubland
__ Dwarf Shrubland
__ Herbaceous (less than 25% woody layers)
__ Nonvascular
__ Sparse Vegetation

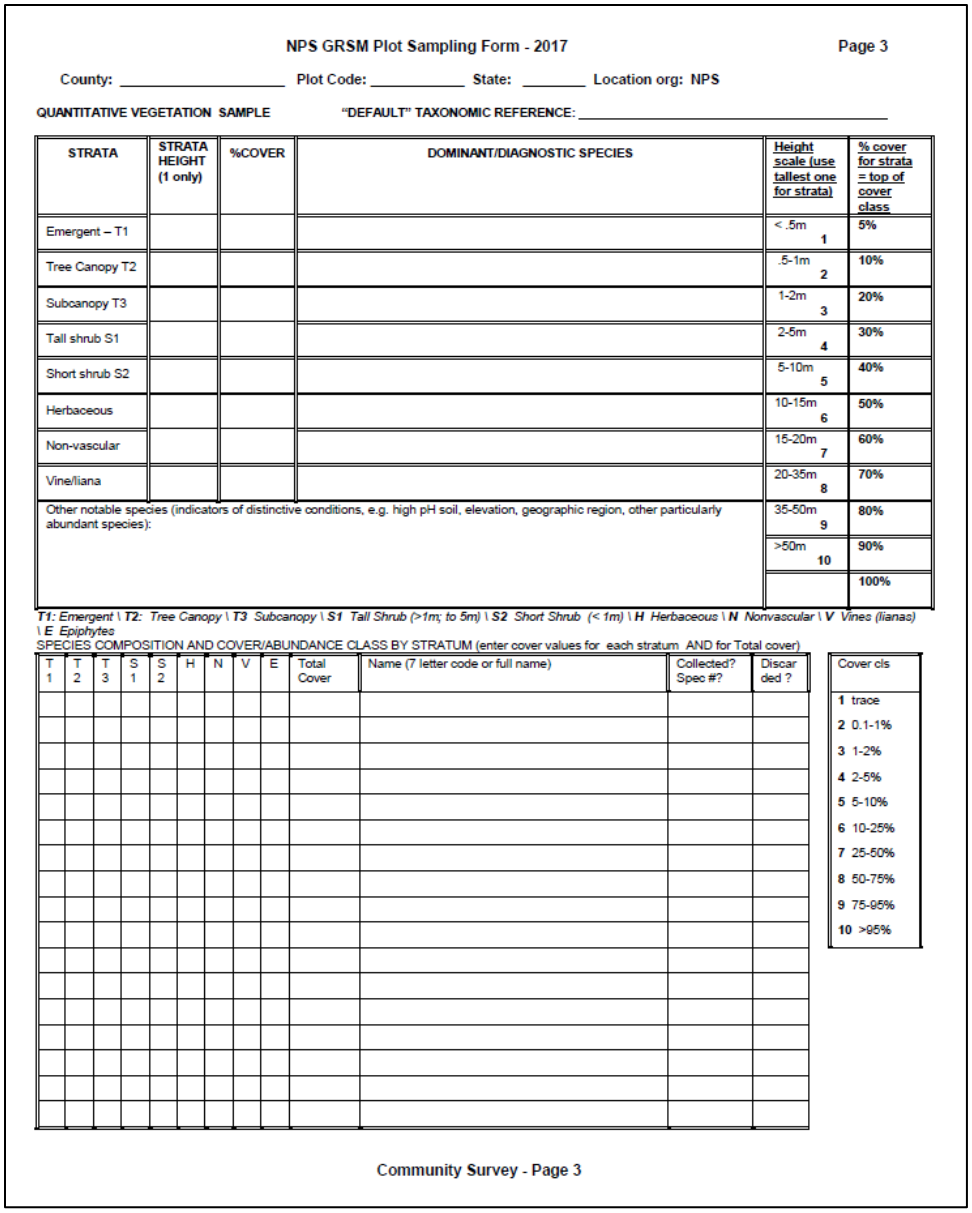
Natural and Anthropogenic Disturbance

_ logging _ fire _ Hydrologic
_ erosion _ trails/roads _ Agriculture
_ grazing/browsing _ wind/ice damage _ Old Growth
_ pine bark beetle _ exotic plants _ Fire Suppression
_ dogwood anthr _ ORV _ Hemlock/Fir Adelgid

Disturbance and animal use comments:

Community Survey - Page 2

Figure A-1b. Graphical example of the second page of a hard-copy data form titled “NPS GRSM Plot Sampling Form - 2017” that was used to survey vegetation community plots for the Great Smoky Mountains National Park vegetation mapping project. This page of the form was used to collect data on the following: county, plot code, state, location organization, and environmental site information including measured slope, measured aspect, topographic position, Cowardin system, landform, rock types present, hydrologic regime, qualitative assessment, soil texture, drainage, ground cover, leaf type, leaf phenology of dominant stratum, physiognomic class, natural and anthropogenic disturbance, and disturbance and animal use.



NPS GRSM Plot Sampling Form - 2017 Page 3

County: _____ Plot Code: _____ State: _____ Location org: NPS

QUANTITATIVE VEGETATION SAMPLE "DEFAULT" TAXONOMIC REFERENCE: _____

STRATA	STRATA HEIGHT (1 only)	%COVER	DOMINANT/DIAGNOSTIC SPECIES	Height scale (use tallest one for strata)	% cover for strata = top of cover class
Emergent – T1				< .5m 1	5%
Tree Canopy T2				.5-1m 2	10%
Subcanopy T3				1-2m 3	20%
Tall shrub S1				2-5m 4	30%
Short shrub S2				5-10m 5	40%
Herbaceous				10-15m 6	50%
Non-vascular				15-20m 7	60%
Vine/liana				20-35m 8	70%
Other notable species (indicators of distinctive conditions, e.g. high pH soil, elevation, geographic region, other particularly abundant species):				35-50m 9	80%
				>50m 10	90%
					100%

T1: Emergent \ T2: Tree Canopy \ T3 Subcanopy \ S1 Tall Shrub (>1m; to 5m) \ S2 Short Shrub (< 1m) \ H Herbaceous \ N Nonvascular \ V Vines (lianas) \ E Epiphytes

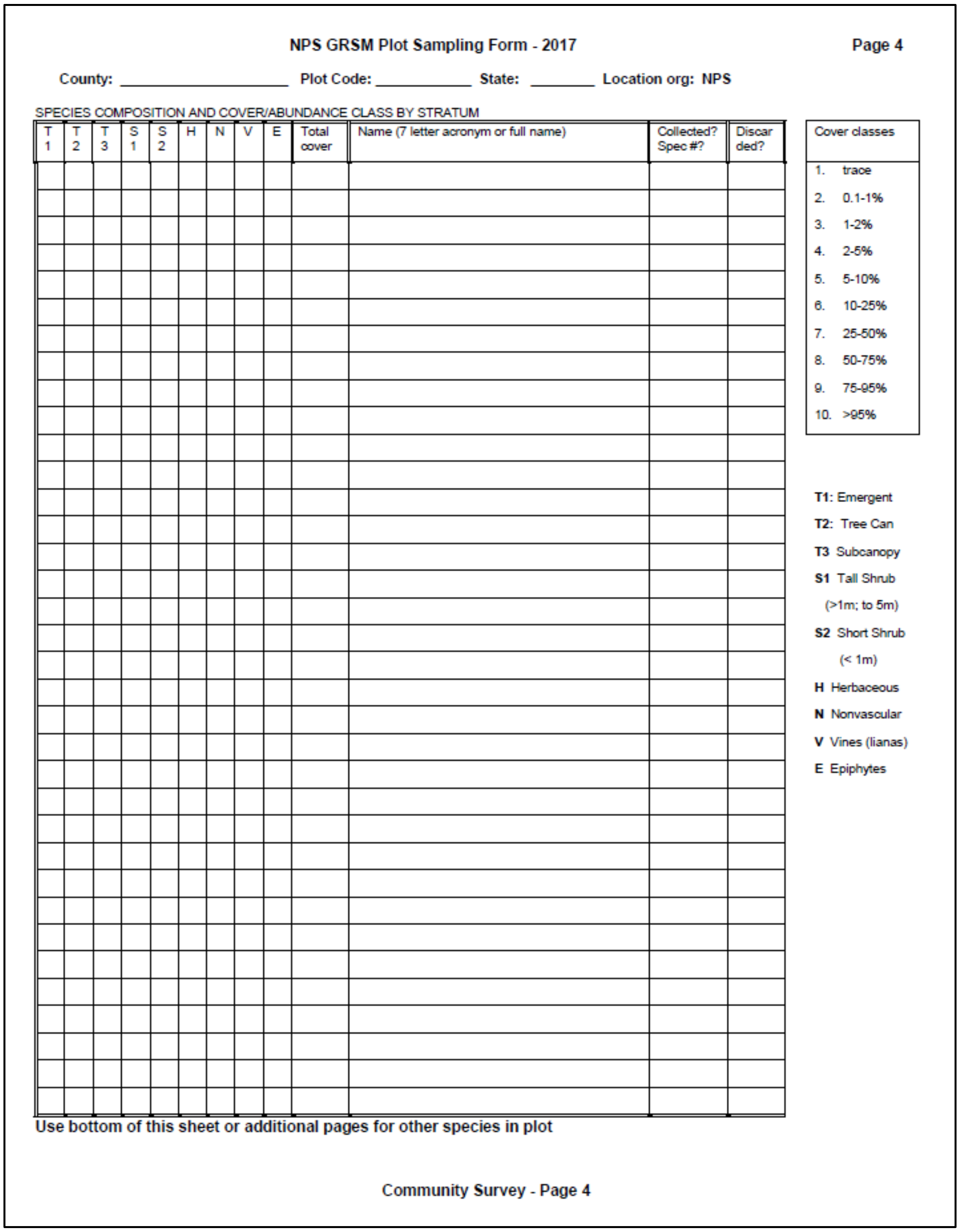
SPECIES COMPOSITION AND COVER/ABUNDANCE CLASS BY STRATUM (enter cover values for each stratum AND for Total cover)

T 1	T 2	T 3	S 1	S 2	H	N	V	E	Total Cover	Name (7 letter code or full name)	Collected? Spec #?	Discarded ?

Cover cls
1 trace
2 0.1-1%
3 1-2%
4 2-5%
5 5-10%
6 10-25%
7 25-50%
8 50-75%
9 75-95%
10 >95%

Community Survey - Page 3

Figure A-1c. Graphical example of the third page of a hard-copy data form titled "NPS GRSM Plot Sampling Form - 2017" that was used to survey vegetation community plots for the Great Smoky Mountains National Park vegetation mapping project. This page of the form was used to collect data on the following: county, plot code, state, location organization, and quantitative vegetation samples including strata, strata height, percent cover dominant or diagnostic species, height scale, percent cover of strata, and species composition and cover or abundance class by stratum.



NPS GRSM Plot Sampling Form - 2017 **Page 4**

County: ____________________ **Plot Code:** ____________ **State:** ________ **Location org: NPS**

SPECIES COMPOSITION AND COVER/ABUNDANCE CLASS BY STRATUM

T 1	T 2	T 3	S 1	S 2	H	N	V	E	Total cover	Name (7 letter acronym or full name)	Collected? Spec #?	Discar ded?

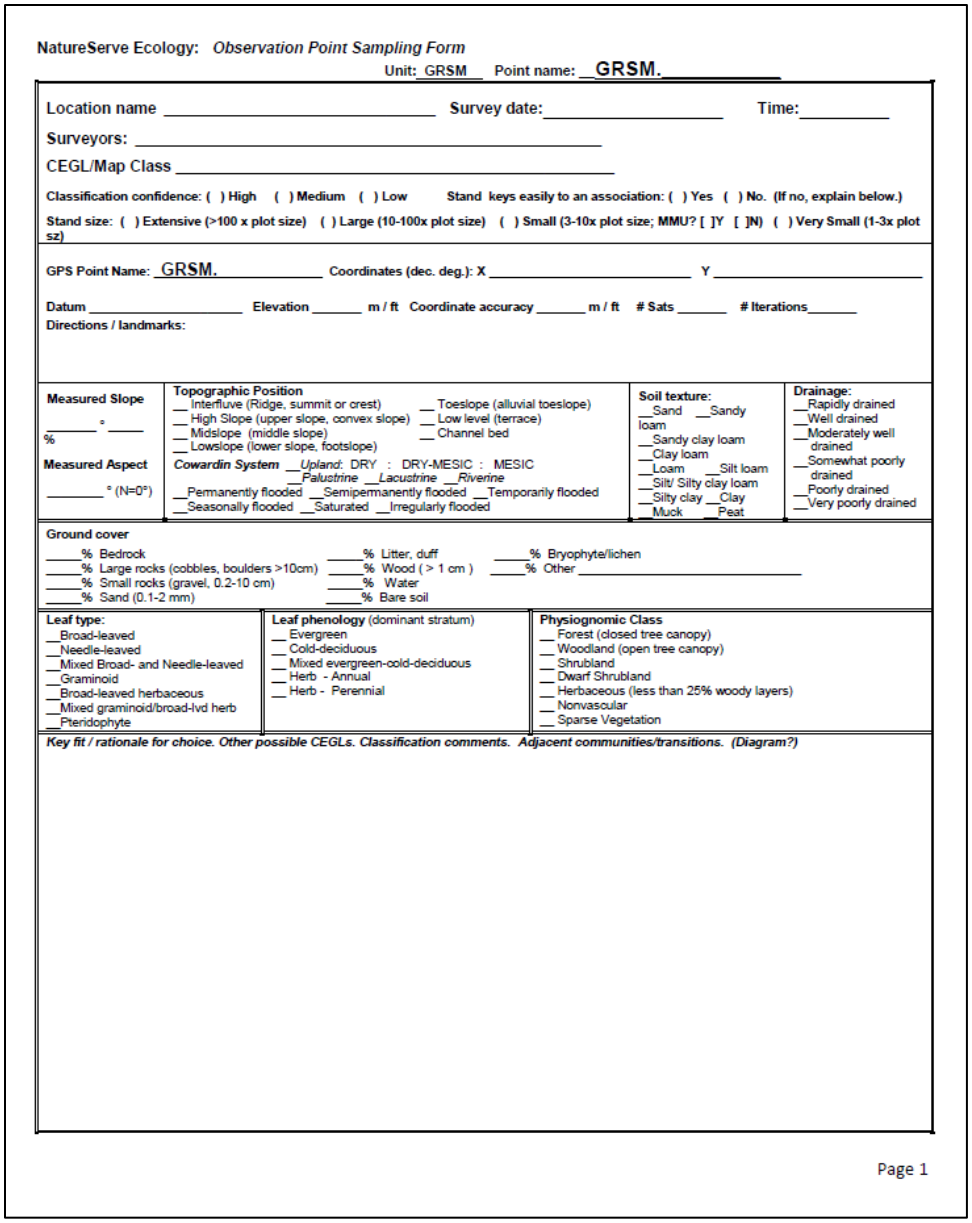
Use bottom of this sheet or additional pages for other species in plot

Cover classes
1. trace
2. 0.1-1%
3. 1-2%
4. 2-5%
5. 5-10%
6. 10-25%
7. 25-50%
8. 50-75%
9. 75-95%
10. >95%

T1: Emergent
T2: Tree Can
T3 Subcanopy
S1 Tall Shrub (>1m; to 5m)
S2 Short Shrub (< 1m)
H Herbaceous
N Nonvascular
V Vines (lianas)
E Epiphytes

Community Survey - Page 4

Figure A-1d. Graphical example of the fourth page of a hard-copy data form titled “NPS GRSM Plot Sampling Form - 2017” that was used to survey vegetation community plots for the Great Smoky Mountains National Park vegetation mapping project. This page of the form was used to collect data on the following: county, plot code, state, location organization, and a continuation of species composition and cover or abundance class by stratum from previous page of the form.



NatureServe Ecology: *Observation Point Sampling Form*

Unit: GRSM Point name: GRSM.

Location name _____ Survey date: _____ Time: _____

Surveyors: _____

CEGL/Map Class _____

Classification confidence: ( ) High ( ) Medium ( ) Low Stand keys easily to an association: ( ) Yes ( ) No. (If no, explain below.)

Stand size: ( ) Extensive (>100 x plot size) ( ) Large (10-100x plot size) ( ) Small (3-10x plot size; MMU? [ ]Y [ ]N) ( ) Very Small (1-3x plot sz)

GPS Point Name: GRSM. Coordinates (dec. deg.): X _____ Y _____

Datum _____ Elevation _____ m / ft Coordinate accuracy _____ m / ft # Sats _____ # Iterations _____

Directions / landmarks:

Measured Slope

_____ ° _____ %

Measured Aspect

_____ ° (N=0°)

Topographic Position

__ Interfluve (Ridge, summit or crest) __ Toeslope (alluvial toeslope)
__ High Slope (upper slope, convex slope) __ Low level (terrace)
__ Midslope (middle slope) __ Channel bed
__ Lowslope (lower slope, footslope)

Cowardin System __*Upland*: DRY : DRY-MESIC : MESIC
__*Palustrine* __*Lacustrine* __*Riverine*
__Permanently flooded __Semipermanently flooded __Temporarily flooded
__Seasonally flooded __Saturated __Irregularly flooded

Soil texture:

__Sand __Sandy loam
__Sandy clay loam
__Clay loam
__Loam __Silt loam
__Silt/ Silty clay loam
__Silty clay __Clay
__Muck __Peat

Drainage:

__Rapidly drained
__Well drained
__Moderately well drained
__Somewhat poorly drained
__Poorly drained
__Very poorly drained

Ground cover

_____% Bedrock
_____% Large rocks (cobbles, boulders >10cm)
_____% Small rocks (gravel, 0.2-10 cm)
_____% Sand (0.1-2 mm)
_____% Litter, duff
_____% Wood (> 1 cm)
_____% Water
_____% Bare soil
_____% Bryophyte/lichen
_____% Other _____

Leaf type:

__Broad-leaved
__Needle-leaved
__Mixed Broad- and Needle-leaved
__Graminoid
__Broad-leaved herbaceous
__Mixed graminoid/broad-lvd herb
__Pteridophyte

Leaf phenology (dominant stratum)

__ Evergreen
__ Cold-deciduous
__ Mixed evergreen-cold-deciduous
__ Herb - Annual
__ Herb - Perennial

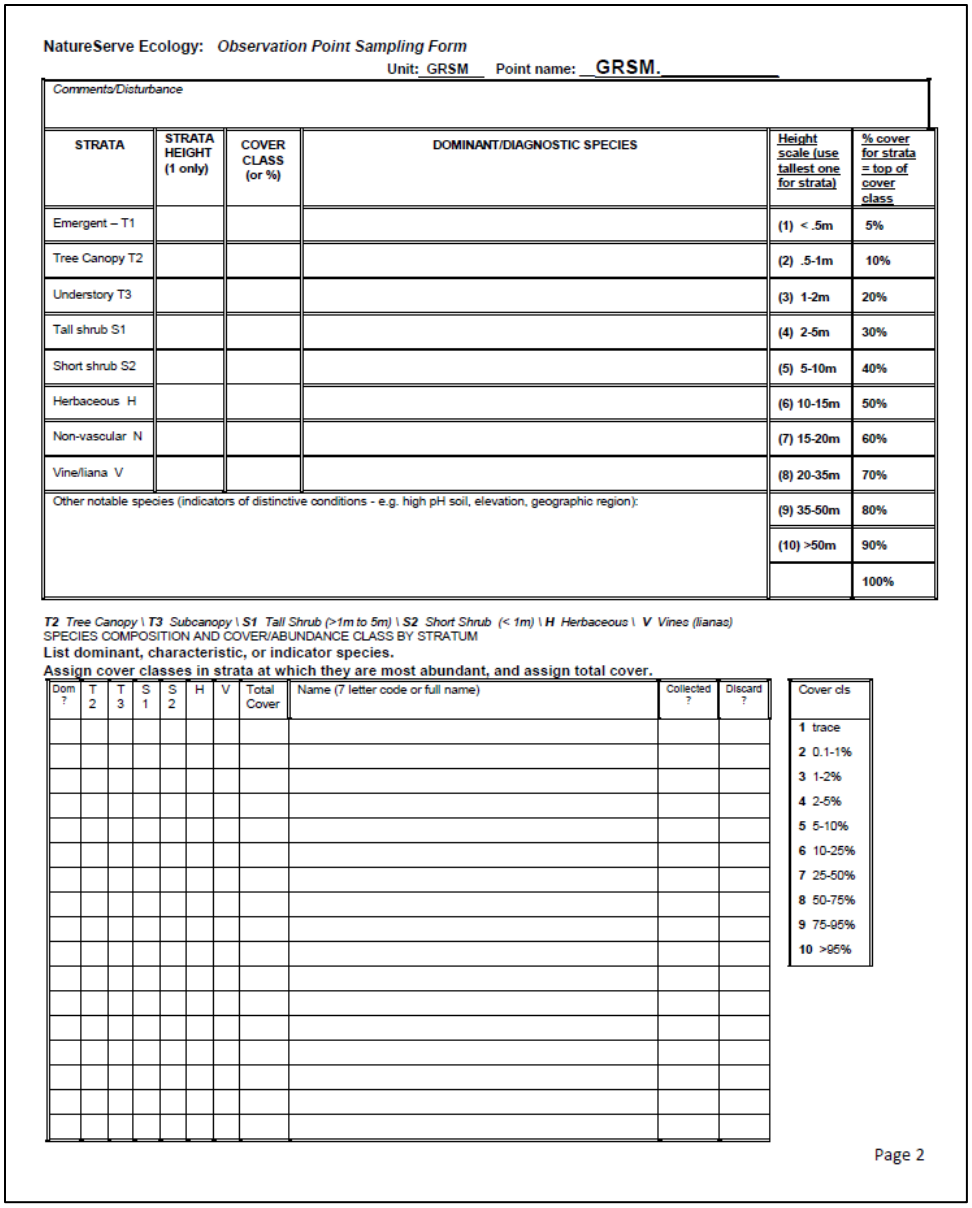
Physiognomic Class

__ Forest (closed tree canopy)
__ Woodland (open tree canopy)
__ Shrubland
__ Dwarf Shrubland
__ Herbaceous (less than 25% woody layers)
__ Nonvascular
__ Sparse Vegetation

Key fit / rationale for choice. Other possible CEGLs. Classification comments. Adjacent communities/transitions. (Diagram?)

Page 1

Figure A-2a. Graphical example of the first page of a hard-copy data form titled “NatureServe Ecology: Observation Point Sampling Form” that was used to observe and document vegetation communities for the Great Smoky Mountains National Park vegetation mapping project. This page of the form was used to collect data on the following: park unit, point name, location name, survey date, survey time, surveyors, community element global or map class code, classification confidence, classification integrity, stand size, global positioning system (GPS) point name, GPS coordinates, GPS datum, GPS elevation, GPS coordinate accuracy, number of GPS satellites, number or GPS iterations, directions and landmarks, measured slope, measured aspect, topographic position, Cowardin system, soil texture, drainage, ground cover, leaf type, leaf phenology of dominant stratum, physiognomic class, and comment field to document classification.



NatureServe Ecology: *Observation Point Sampling Form*

Unit: GRSM Point name: GRSM.

Comments/Disturbance

STRATA	STRATA HEIGHT (1 only)	COVER CLASS (or %)	DOMINANT/DIAGNOSTIC SPECIES	Height scale (use tallest one for strata)	% cover for strata = top of cover class
Emergent – T1				(1) < .5m	5%
Tree Canopy T2				(2) .5-1m	10%
Understory T3				(3) 1-2m	20%
Tall shrub S1				(4) 2-5m	30%
Short shrub S2				(5) 5-10m	40%
Herbaceous H				(6) 10-15m	50%
Non-vascular N				(7) 15-20m	60%
Vine/liana V				(8) 20-35m	70%
Other notable species (indicators of distinctive conditions - e.g. high pH soil, elevation, geographic region):				(9) 35-50m	80%
				(10) >50m	90%
					100%

T2 Tree Canopy \ T3 Subcanopy \ S1 Tall Shrub (>1m to 5m) \ S2 Short Shrub (< 1m) \ H Herbaceous \ V Vines (lianas)

SPECIES COMPOSITION AND COVER/ABUNDANCE CLASS BY STRATUM

List dominant, characteristic, or indicator species.

Assign cover classes in strata at which they are most abundant, and assign total cover.

Dom ?	T 2	T 3	S 1	S 2	H	V	Total Cover	Name (7 letter code or full name)	Collected ?	Discard ?

Cover cls
1 trace
2 0.1-1%
3 1-2%
4 2-5%
5 5-10%
6 10-25%
7 25-50%
8 50-75%
9 75-95%
10 >95%

Page 2

Figure A-2b. Graphical example of the second page of a hard-copy data form titled “NatureServe Ecology: Observation Point Sampling Form” that was used to observe and document vegetation communities for the Great Smoky Mountains National Park vegetation mapping project. This page of the form was used to collect data on the following: park unit, point name, location name, site disturbance, strata, strata height, cover class, dominant or diagnostic species, heigh scale, percent cover for strata, and species composition and cover or abundance class by stratum.

NatureServe Ecology: ***Observation Point Sampling Form***

Unit: GRSM **Point name:** GRSM.

SPECIES COMPOSITION AND COVER/ABUNDANCE CLASS BY STRATUM

List dominant, characteristic, or indicator species.

Assign cover classes in strata at which they are most abundant, and assign total cover.

Dom ?	T2	T3	S1	S2	H	V	Total Cover	Name (7 letter code or full name)	Collected ?	Discard ?

Cover cls
1 trace
2 0.1-1%
3 1-2%
4 2-5%
5 5-10%
6 10-25%
7 25-50%
8 50-75%
9 75-95%
10 >95%

T2 Tree Can
T3 Subcanopy
S1 Tall Shrub (>1m; to 5m)
S2 Short Shrub (< 1m)
H Herbaceous
V Vines (lianas)

Page 3

Figure A-2c. Graphical example of the third page of a hard-copy data form titled “NatureServe Ecology: Observation Point Sampling Form” that was used to observe and document vegetation communities for the Great Smoky Mountains National Park vegetation mapping project. This page of the form was used to collect data on the following: park unit, point name, and a continuation of species composition and cover or abundance class by stratum from previous page of the form.

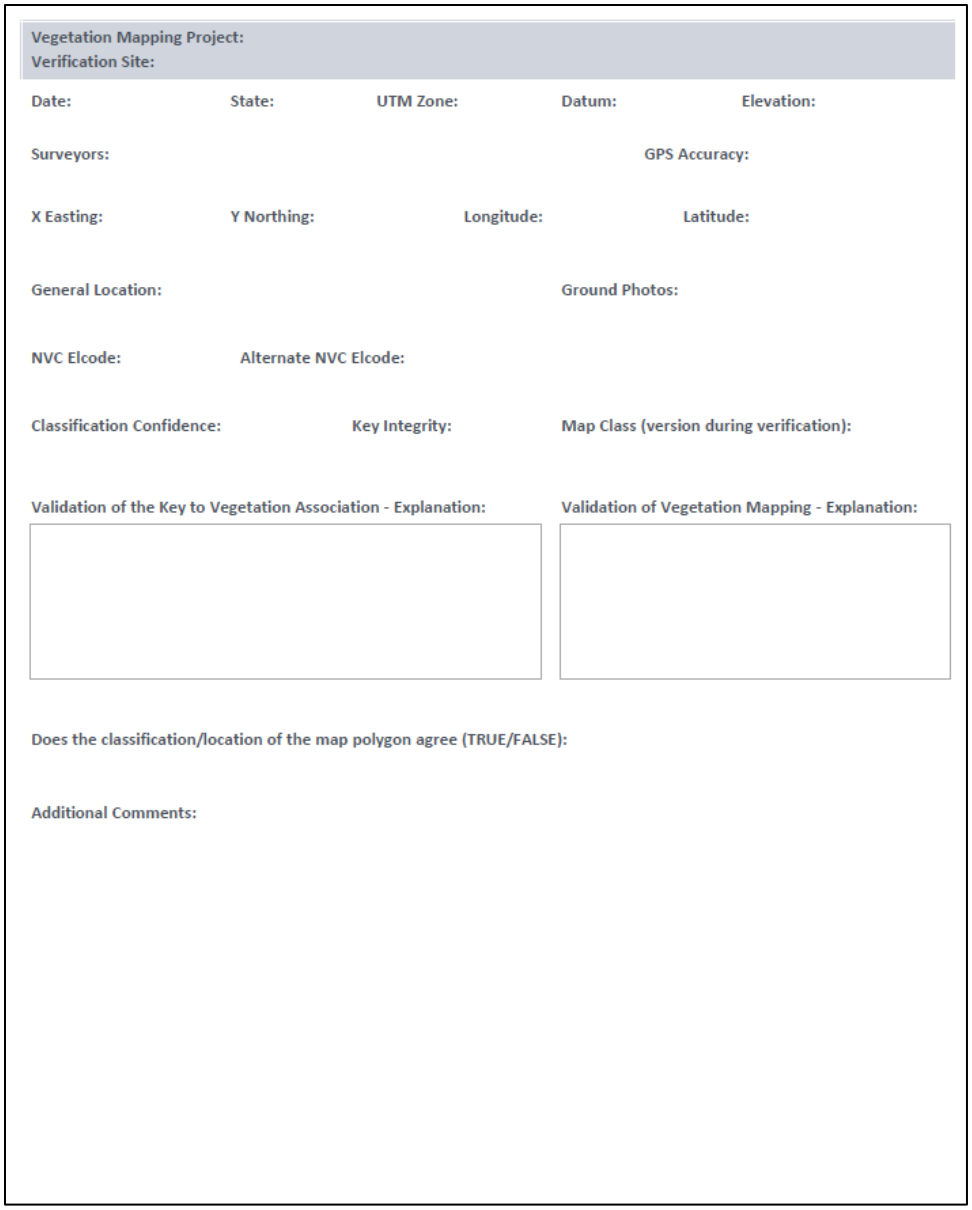
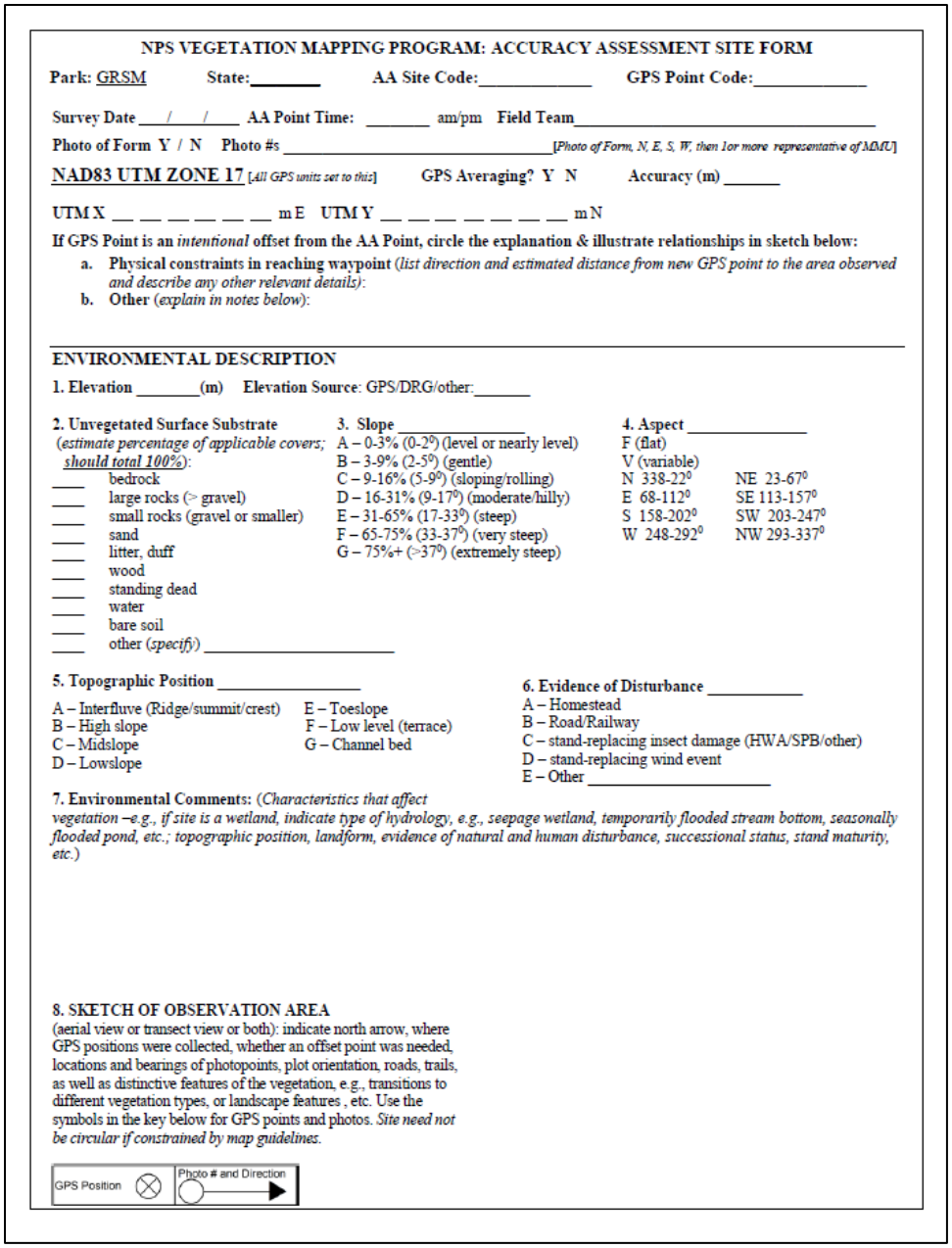


Figure A-3a. Graphical example of an electronic verification site form that was used to verify vegetation mapping and classification for the Great Smoky Mountains National Park vegetation mapping project. This form was used to collect data on the following: vegetation mapping project identification, verification site number, date, state, universal transverse Mercator zone, datum, elevation, surveyors, global positioning system (GPS) accuracy, GPS coordinates X easting and Y northing, longitude and latitude, general location description, ground photos, National Vegetation Classification (NVC) Elcode, alternate NVC Elcode, classification confidence, vegetation key integrity, map class version during verification, validation of key to vegetation association, validation of vegetation mapping, classification and map polygon agreement, and additional comments.



NPS VEGETATION MAPPING PROGRAM: ACCURACY ASSESSMENT SITE FORM

Park: GRSM State:_____ AA Site Code:_____ GPS Point Code:_____

Survey Date ___/___/___ AA Point Time: _____ am/pm Field Team_____

Photo of Form Y / N Photo #s _____[Photo of Form, N, E, S, W, then 1or more representative of MMU]

NAD83 UTM ZONE 17 [All GPS units set to this] GPS Averaging? Y N Accuracy (m) _____

UTM X __ __ __ __ __ __ m E UTM Y __ __ __ __ __ __ __ m N

If GPS Point is an *intentional* offset from the AA Point, circle the explanation & illustrate relationships in sketch below:

a. Physical constraints in reaching waypoint (*list direction and estimated distance from new GPS point to the area observed and describe any other relevant details*):
b. Other (*explain in notes below*):

ENVIRONMENTAL DESCRIPTION

1. Elevation _____(m) Elevation Source: GPS/DRG/other:_____

2. Unvegetated Surface Substrate (*estimate percentage of applicable covers; should total 100%*):
____ bedrock
____ large rocks (> gravel)
____ small rocks (gravel or smaller)
____ sand
____ litter, duff
____ wood
____ standing dead
____ water
____ bare soil
____ other (*specify*) _____

3. Slope _____
A – 0-3% (0-2^0) (level or nearly level)
B – 3-9% (2-5^0) (gentle)
C – 9-16% (5-9^0) (sloping/rolling)
D – 16-31% (9-17^0) (moderate/hilly)
E – 31-65% (17-33^0) (steep)
F – 65-75% (33-37^0) (very steep)
G – 75%+ (>37^0) (extremely steep)

4. Aspect _____
F (flat)
V (variable)
N 338-22^0 NE 23-67^0
E 68-112^0 SE 113-157^0
S 158-202^0 SW 203-247^0
W 248-292^0 NW 293-337^0

5. Topographic Position _____
A – Interfluve (Ridge/summit/crest)
B – High slope
C – Midslope
D – Lowslope
E – Toeslope
F – Low level (terrace)
G – Channel bed

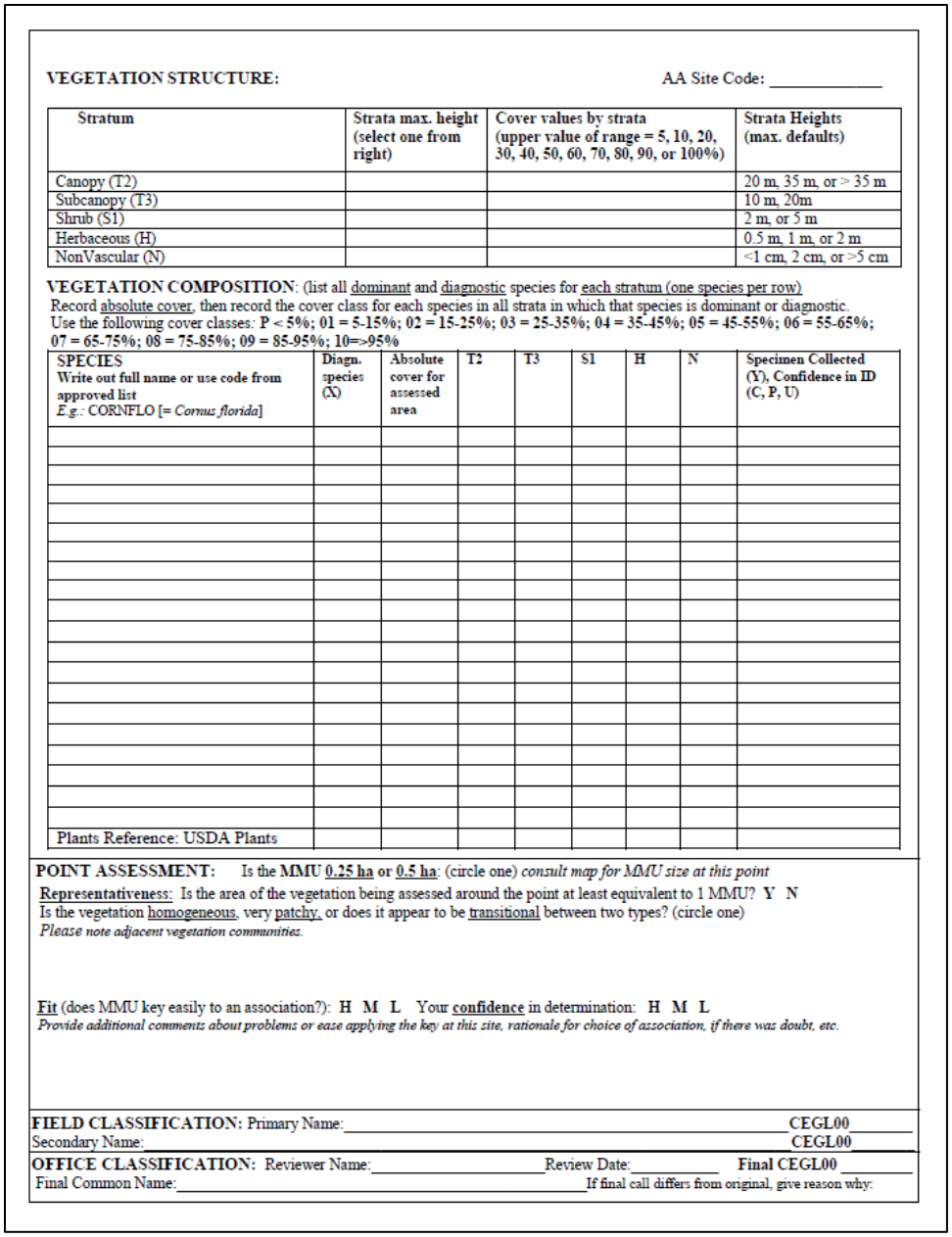
6. Evidence of Disturbance _____
A – Homestead
B – Road/Railway
C – stand-replacing insect damage (HWA/SPB/other)
D – stand-replacing wind event
E – Other _____

7. Environmental Comments: (*Characteristics that affect vegetation –e.g., if site is a wetland, indicate type of hydrology, e.g., seepage wetland, temporarily flooded stream bottom, seasonally flooded pond, etc.; topographic position, landform, evidence of natural and human disturbance, successional status, stand maturity, etc.*)

8. SKETCH OF OBSERVATION AREA
(aerial view or transect view or both): indicate north arrow, where GPS positions were collected, whether an offset point was needed, locations and bearings of photopoints, plot orientation, roads, trails, as well as distinctive features of the vegetation, e.g., transitions to different vegetation types, or landscape features , etc. Use the symbols in the key below for GPS points and photos. *Site need not be circular if constrained by map guidelines.*

GPS Position ⊗ Photo # and Direction ○→

Figure A-4a. Graphical example of the first page of a hard-copy data form titled “NPS VEGETATION MAPPING PROGRAM: ACCURACY ASSESSMENT SITE FORM” that was used to survey accuracy assessment sites for the Great Smoky Mountains National Park vegetation mapping project. This page of the form was used to collect data on the following: park identification, state, accuracy assessment (AA) site code, global positioning system (GPS) code, survey date, AA point time, field team members, photograph of form, photographs of AA site including cardinal directions and representative of site, GPS projection and Universal Transverse Mercator (UTM) zone, GPS averaging, GPS accuracy, GPS UTM coordinates X easting and Y northing, GPS offset information, and environmental description including elevation, elevation source, unvegetated surface substrate, slope, aspect, topographic position, evidence of disturbance, environmental comments, and sketch of observation area.



VEGETATION STRUCTURE: AA Site Code: _____

Stratum	Strata max. height (select one from right)	Cover values by strata (upper value of range = 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100%)	Strata Heights (max. defaults)
Canopy (T2)			20 m, 35 m, or > 35 m
Subcanopy (T3)			10 m, 20m
Shrub (S1)			2 m, or 5 m
Herbaceous (H)			0.5 m, 1 m, or 2 m
NonVascular (N)			<1 cm, 2 cm, or >5 cm

VEGETATION COMPOSITION: (list all dominant and diagnostic species for each stratum (one species per row)
Record absolute cover, then record the cover class for each species in all strata in which that species is dominant or diagnostic.
Use the following cover classes: P < 5%; 01 = 5-15%; 02 = 15-25%; 03 = 25-35%; 04 = 35-45%; 05 = 45-55%; 06 = 55-65%; 07 = 65-75%; 08 = 75-85%; 09 = 85-95%; 10=>95%

SPECIES Write out full name or use code from approved list *E.g.*: CORNFLO [= *Cornus florida*]	Diagn. species (X)	Absolute cover for assessed area	T2	T3	S1	H	N	Specimen Collected (Y), Confidence in ID (C, P, U)
Plants Reference: USDA Plants								

POINT ASSESSMENT: Is the **MMU 0.25 ha or 0.5 ha**: (circle one) *consult map for MMU size at this point*

Representativeness: Is the area of the vegetation being assessed around the point at least equivalent to 1 MMU? **Y N**
Is the vegetation homogeneous, very patchy, or does it appear to be transitional between two types? (circle one)
Please note adjacent vegetation communities.

Fit (does MMU key easily to an association?): **H M L** Your **confidence** in determination: **H M L**
Provide additional comments about problems or ease applying the key at this site, rationale for choice of association, if there was doubt, etc.

FIELD CLASSIFICATION: Primary Name:_____ **CEGL00**_____
Secondary Name:_____ **CEGL00**_____
OFFICE CLASSIFICATION: Reviewer Name:_____ Review Date:_____ **Final CEGL00**_____
Final Common Name:_____ If final call differs from original, give reason why:

Figure A-4b. Graphical example of the second page of a hard-copy data form titled “NPS VEGETATION MAPPING PROGRAM: ACCURACY ASSESSMENT SITE FORM” that was used to survey accuracy assessment sites for the Great Smoky Mountains National Park vegetation mapping project. This page of the form was used to collect data on the following: accuracy assessment (AA) site code; vegetation structure including stratum, strata maximum height, cover values by strata, strata heights; vegetation composition of species; point assessment representativeness and fit; and field and office classifications.

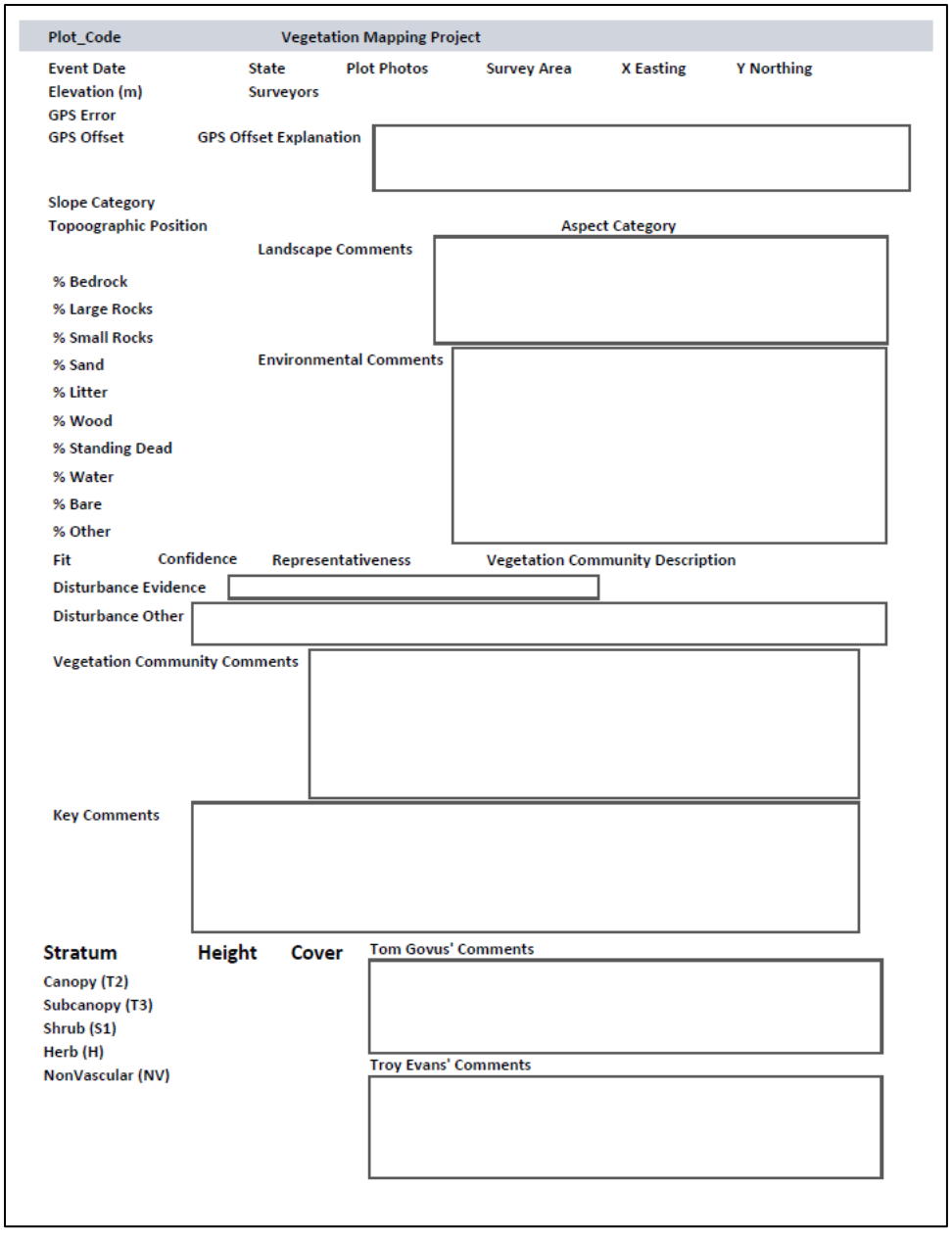


Figure A-5a. Graphical example of the first page of an electronic that was used to survey accuracy assessment sites for the Great Smoky Mountains National Park vegetation mapping project. This page of the form was used to collect data on the following: plot code and vegetation mapping project identification; event date, state, plot photos, survey area, surveyors, global positioning system (GPS) coordinates X easting and Y northing, GPS elevation, GPS error, and GPS offset and explanation; slope category, topographic position, aspect category, landscape comments, and environmental comments; classification fitness, confidence, representativeness, vegetation community description and comments, disturbance comments, and classification key comments; and stratum, height, cover, and comments.

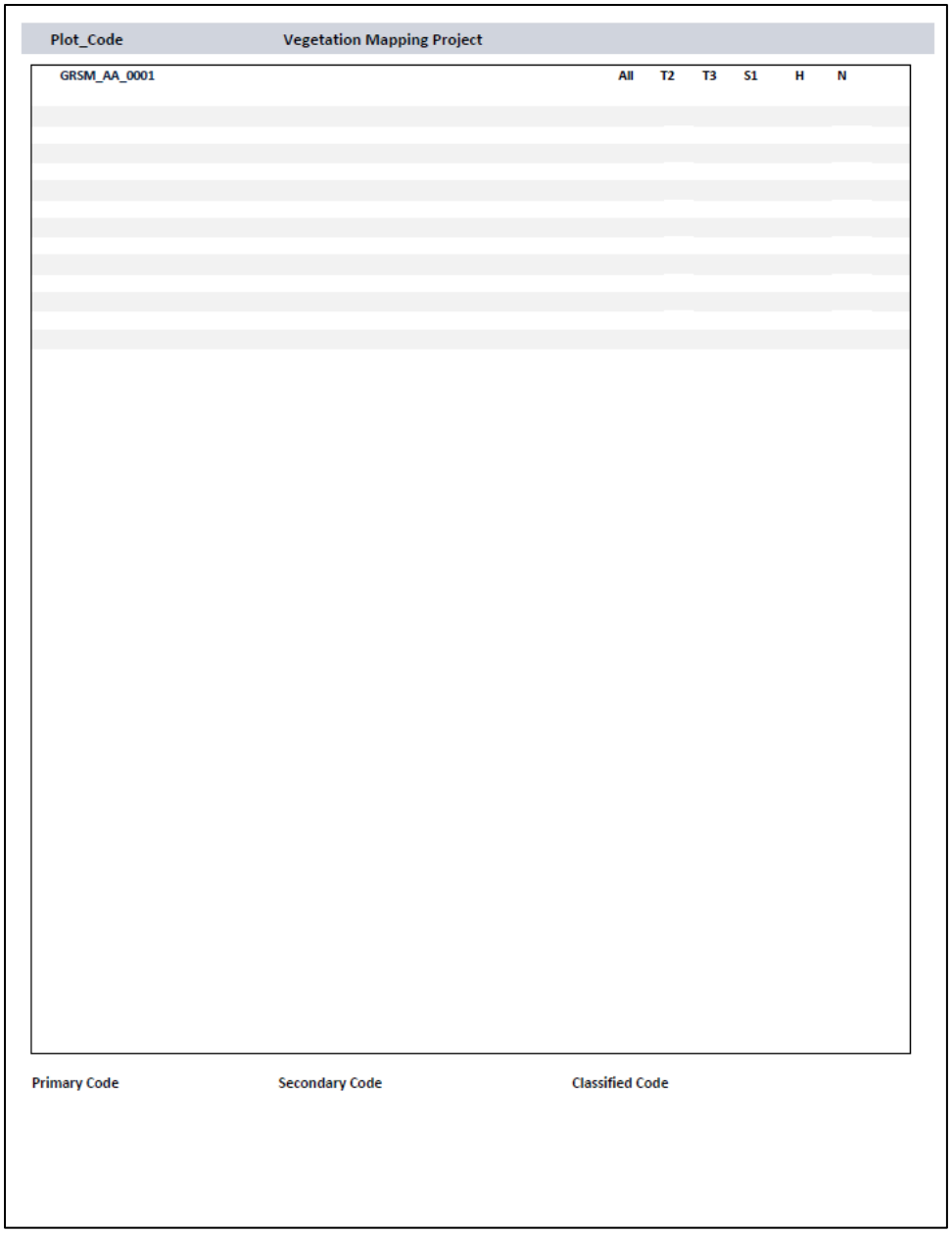


Figure A-5b. Graphical example of the first page of an electronic that was used to survey accuracy assessment sites for the Great Smoky Mountains National Park vegetation mapping project. This page of the form was used to collect data on the following: plot code, vegetation mapping project identification vegetation composition of species, primary classification code, secondary classification code, and classified code.

Appendix B: Descriptions of Map Classes

Explanation of Map-Class Descriptions

This appendix provides descriptions of the 52 map classes used to map the Great Smoky Mountains National Park (GRSM, also referred to as the "Park"), including the Foothills Parkway, for the National Park Service (NPS) Vegetation Mapping Inventory (VMI) Program. Of these 52 map classes, 46 represent natural (including ruderal) vegetation types that consist of 90 U.S. National Vegetation Classification (USNVC) association types, 1 park-special type, 1 map-special type, and 1 USNVC cultural type[12]. For the remaining 6 map classes, 4 represent USNVC cultural types for agricultural and developed areas and 2 represent non-USNVC types for nonvegetated open water and nonvegetated rock.

For those map classes representing vegetation types in the USNVC, the following documents complement the map-class descriptions in this appendix:

- Associations and Alliances of Great Smoky Mountains National Park (inclusive of the Foothills Parkway) (NatureServe 2020) and
- Field Key to Vegetation Types of Great Smoky Mountains National Park (inclusive of the Foothills Parkway) (White et al. 2020).

These documents are posted to the NPS Integrated Resource Management Applications (IRMA) Portal at the location associated with this GRSM vegetation mapping project (https://irma.nps.gov/DataStore/Reference/Profile/2165636).

Each map-class description provides the formal map-class code and name used for mapping. For those map classes representing a single vegetation type in the USNVC, the type's common name was used (e.g., Southern Appalachian Beech Gap). For those map classes representing more than one vegetation type, a comparable name was derived (e.g., the Mixed Oak - White Pine Forest map class for the collective USNVC associations of Appalachian White Pine - Mesic Oak Forest and Appalachian White Pine - Xeric Oak Forest). For map classes representing cultural vegetation, a generic name was derived (i.e., Developed Land). For the map classes representing non-USNVC features, a generic name was derived (i.e., Flowing and Ponded Water).

The vegetation classification name(s) and code(s) that the map class represents are provided at the beginning of each map-class description, except for nonvegetated classes. Each map class is described with a focus on how the class presents in the GRSM landscape, noting that this description may not reflect how the various vegetation types present across their respective range. Descriptions are from a mapping, rather than an ecological, perspective, but ecological concepts relevant to the mapping effort were integrated into the map-class description. Full ecological descriptions of each

[12]The *Picea abies* Forest Plantation Cultural Subtype (CST007167) represented by the FXNS map class is included with the natural (including ruderal) types because it is no longer managed as a cultural type at GRSM and functions as a natural ruderal forest.

vegetation association are available in "Associations and Alliances of Great Smoky Mountains National Park (inclusive of the Foothills Parkway)" (NatureServe 2020).

Tree species are assumed to be of heights higher than 5 meters (m), unless otherwise specified in the description. Unless otherwise noted, herbaceous types have greater than 10% herbaceous cover and less than 25% total tree and shrub canopy closure, shrubland types have greater than 25% shrub canopy closure and less than 25% tree canopy closure, woodlands have greater than 25% tree canopy closure, and forests typically have greater than 60% tree canopy closure, but can be less than 60% canopy closure depending on the environment. Elevations are provided in meters above mean sea level.

Adjectives are used in the map-class descriptions to provide a general idea of the commonness of each map class by area and percent cover of the GRSM vegetation map layer. These adjectives are detailed in Table B-1.

Table B-1. Adjectives used to describe map-class commonness of occurrence by area and percent cover of the Great Smoky Mountains National Park vegetation map layer.

Adjective	Area (hectares)	Percent cover
Extremely rare	<20.9	<0.01
Rare	21.0 to 208.8	0.01 to <0.1
Uncommon	208.8 to1,033.3	0.1 to <0.5
Common	1,033.4 to 5,250.8	0.5 to <2.5
Very common	>5,250.9	>2.5

Unless otherwise specified, discussions regarding map-class signatures or presentations are referenced to the color-infrared viewing of the project's four-band aerial imagery set used during the mapping process. This set of imagery is succinctly stated as "project imagery" in the map-class descriptions.

When accuracy assessment (AA) results are reported in the map-class description, two views are discussed—mapped too aggressively and mapped too conservatively. The view of "mapped too aggressively" refers to errors in the users' accuracy. The users' accuracy presents the probability that an AA site in the tested map class does not have a vegetation type that is represented by the map class. This probability is an error of commission indicating where too much area was mapped as the tested map class. The lower the users' accuracy for a map class, the higher the likelihood that the map class was overmapped (i.e., mapped too aggressively). The view of "mapped too conservatively" refers to errors in the producers' accuracy. The producers' accuracy presents the probability that an AA site in a different map class has a vegetation type that is represented by the tested map class. This probability is an error of omission indicating where too little area was mapped

as the tested map class. The lower the producers' accuracy for a map class, the higher the likelihood that the map class was undermapped (i.e., mapped too conservatively).

Straight accuracies are listed for users' and producers' in the reporting of AA results. When straight accuracies are below 80%, the 90% confidence intervals are provided to present where the interval range is in regard to the 80% accuracy standard set by the NPS VMI Program. The 90% confidence intervals to users' and producers' accuracies for all map classes that were included in the AA study are provided in a contingency matrix. Like the two classification products listed previously, this contingency table is posted to the NPS IRMA Portal at the location associated with this project (https://irma.nps.gov/DataStore/Reference/Profile/2165636).

Along with text descriptions of the map classes, images from field pictures are provided when possible to visually depict the vegetation types and nonvegetation features that the map classes represent. The images are a partial representation; capturing all variations within a map class would not be possible.

Map-classification codes, names, and their corresponding crosswalk (cross-reference) to vegetation types are listed in Table B-2. The map class that represents nonvegetation features (water and rock), which is not included in the USNVC, also is included in Table B-2. The map classification is listed alphabetically by map-class code in Table B-3 at the end of this appendix.

Minimum Mapping Units

The NPS VMI Program's standard minimum mapping unit (MMU) of 0.5 hectare (ha) was applied to mapping forest map classes. For woodland, shrubland, herbaceous vegetation, cultural areas, and nonvegetated map classes, an MMU of 0.25 ha was applied. The smaller MMU was applied because of the consistent small patch presentation of vegetation types represented by the map classes.

For polygons that represent vegetation crossing outside the boundary for the GRSM vegetation mapping project, mappers allowed the polygons to be mapped less than the MMU if the vegetation that continued over the project boundary was contiguous and covered at least the standard MMU for that map class. In these instances, map classes with a 0.5-ha MMU were mapped down to 0.1 ha, and map classes with a 0.25-ha MMU were mapped down to 0.05 ha. For example, a 0.18-ha polygon of the Ruderal Tuliptree - Walnut Forest (FXTW) map class would be mapped inside the boundary if at least 0.32 ha of contiguous connected FXTW was outside the boundary.

Table B-2. Map-class codes and names, with crosswalk to vegetation types in the U.S. National Vegetation Classification for the Great Smoky Mountains National Park vegetation mapping project.

Map-class category	Map class	Vegetation type
High-Elevation Deciduous Forest & Woodland	FBGP - Southern Appalachian Beech Gap	*Fagus grandifolia* / *Carex pensylvanica - Ageratina altissima* var. *roanensis* Forest (CEGL006130)
	FNHH - Northern Hardwood High-Elevation Forest	*Aesculus flava - Betula alleghaniensis - Acer saccharum* / *Caulophyllum thalictroides - Actaea podocarpa* Forest (CEGL004973)
	FNHH - Northern Hardwood High-Elevation Forest	*Betula alleghaniensis - Tilia americana* var. *heterophylla* / *Acer spicatum* / *Ribes cynosbati* / *Dryopteris marginalis* Forest (CEGL004982)
	FNHH - Northern Hardwood High-Elevation Forest	*Betula alleghaniensis* / *Ribes glandulosum* / *Polypodium appalachianum* Forest (CEGL006124)
	FNHH - Northern Hardwood High-Elevation Forest	*Betula alleghaniensis - Fagus grandifolia* / *Viburnum lantanoides* / *Eurybia chlorolepis - Dryopteris intermedia* Forest (CEGL007285)
	FHEO - High-Elevation Oak Forest	*Quercus alba* / *Kalmia latifolia* Forest (CEGL007295)
	FHEO - High-Elevation Oak Forest	*Quercus rubra* / *Carex pensylvanica - Ageratina altissima* var. *roanensis* Forest (CEGL007298)
	FHEO - High-Elevation Oak Forest	*Quercus rubra* / (*Kalmia latifolia*, *Rhododendron catawbiense*, *Rhododendron maximum*) / *Galax urceolata* Forest (CEGL007299)
	FHEO - High-Elevation Oak Forest	*Quercus rubra* / (*Vaccinium simulatum*, *Rhododendron calendulaceum*) / (*Dennstaedtia punctilobula*, *Thelypteris noveboracensis*) Forest (CEGL007300)
High-Elevation Mixed Deciduous-Conifer Forest	FBHH - Blue Ridge Hemlock - Northern Hardwood Forest	*Betula alleghaniensis* - (*Tsuga canadensis*) / *Rhododendron maximum* / (*Leucothoe fontanesiana*) Forest (CEGL007861)
	FSHE - Red Spruce - Northern Hardwood Forest (Shrub Type)	*Picea rubens* - (*Betula alleghaniensis*, *Aesculus flava*) / *Rhododendron* (*maximum*, *catawbiense*) Forest (CEGL004983)
	FSHH - Red Spruce - Northern Hardwood Forest (Herb Type)	*Picea rubens* - (*Betula alleghaniensis*, *Aesculus flava*) / *Viburnum lantanoides* / *Solidago glomerata* Forest (CEGL006256)

Table B-2 (continued). Map-class codes and names, with crosswalk to vegetation types in the U.S. National Vegetation Classification for the Great Smoky Mountains National Park vegetation mapping project.

Map-class category	Map class	Vegetation type
High-Elevation Spruce-Fir Forest & Woodland	FFFS - Fraser Fir / Mixed Shrub Forest	*Abies fraseri* / *Viburnum lantanoides* / *Dryopteris campyloptera* - *Oxalis montana* / *Hylocomium splendens* Forest (CEGL006049)
	FFFS - Fraser Fir / Mixed Shrub Forest	*Abies fraseri* / (*Rhododendron catawbiense*, *Rhododendron carolinianum*) Forest (CEGL006308)
	FSFD - Red Spruce - Fraser Fir Forest (Deciduous Shrub Type)	*Picea rubens* - (*Abies fraseri*) / *Vaccinium erythrocarpum* / *Dryopteris campyloptera* / *Hylocomium splendens* Forest (CEGL007131)
	FSFE - Spruce - Fir / Evergreen Shrub Forest	*Picea rubens* - (*Tsuga canadensis*) / *Rhododendron maximum* Forest (CEGL006152)
	FSFE - Spruce - Fir / Evergreen Shrub Forest	*Picea rubens* - (*Abies fraseri*) / (*Rhododendron catawbiense*, *Rhododendron maximum*) Forest (CEGL007130)
High-Elevation Pine Woodland	WTMH - Blue Ridge Table Mountain Pine - Pitch Pine Woodland (High-Elevation Type)	*Pinus rigida* - (*Pinus pungens*) / *Rhododendron catawbiense* - *Kalmia latifolia* / *Galax urceolata* Woodland (CEGL004985)
Low-Elevation Oak Forest	FCES - Chestnut Oak / Evergreen Shrub Forest	*Quercus* (*montana*, *coccinea*) / *Kalmia latifolia* / (*Galax urceolata*, *Gaultheria procumbens*) Forest (CEGL006271)
	FCES - Chestnut Oak / Evergreen Shrub Forest	*Quercus montana* - *Quercus rubra* / *Rhododendron maximum* / *Galax urceolata* Forest (CEGL006286)
	FCES - Chestnut Oak / Evergreen Shrub Forest	*Quercus alba* - *Quercus coccinea* - *Quercus falcata* / *Kalmia latifolia* - *Vaccinium pallidum* Forest (CEGL007691)
	FCES - Chestnut Oak / Evergreen Shrub Forest	*Quercus montana* - (*Quercus coccinea*) / *Carya pallida* / *Vaccinium arboreum* - *Vaccinium pallidum* Forest (CEGL008431)
	FOHM - Mixed Oak / Mixed Shrub and Herb Forest	*Quercus rubra* - *Acer rubrum* / *Pyrularia pubera* / *Thelypteris noveboracensis* Forest (CEGL006192)
	FOHM - Mixed Oak / Mixed Shrub and Herb Forest	*Quercus alba* - *Quercus* (*rubra*, *montana*) / *Rhododendron calendulaceum* - (*Gaylussacia ursina*) Forest (CEGL007230)
	FOHM - Mixed Oak / Mixed Shrub and Herb Forest	*Quercus montana* - (*Quercus rubra*) - *Carya* spp. / *Oxydendrum arboreum* - *Cornus florida* Forest (CEGL007267)

Table B-2 (continued). Map-class codes and names, with crosswalk to vegetation types in the U.S. National Vegetation Classification for the Great Smoky Mountains National Park vegetation mapping project.

Map-class category	Map class	Vegetation type
Low-Elevation Oak Forest (continued)	FOHM - Mixed Oak / Mixed Shrub and Herb Forest	*Quercus alba* - *Quercus rubra* - *Quercus montana* / *Collinsonia canadensis* - *Podophyllum peltatum* Forest (CEGL007692)
	FOHM - Mixed Oak / Mixed Shrub and Herb Forest	*Quercus montana* - *Juniperus virginiana* - (*Pinus virginiana*) / *Philadelphus hirsutus* - *Celtis occidentalis* Woodland (CEGL007720)
	FOHM - Mixed Oak / Mixed Shrub and Herb Forest	*Quercus rubra* - *Tilia americana* var. *heterophylla* - (*Halesia tetraptera* var. *monticola*) / *Collinsonia canadensis* - *Prosartes lanuginosa* Forest (CEGL007878)
	FOHM - Mixed Oak / Mixed Shrub and Herb Forest	*Quercus alba* - *Quercus falcata* / *Vaccinium* (*arboreum*, *hirsutum*, *pallidum*) Forest (CEGL008567)
	FROH - Ridge-and-Valley Oak - Hardwood Forest	*Quercus alba* - *Quercus rubra* - *Carya ovalis* / *Acer saccharum* / *Polystichum acrostichoides* Forest (CEGL007233)
	FROH - Ridge-and-Valley Oak - Hardwood Forest	*Quercus alba* - *Quercus rubra* - *Carya ovata* / *Cercis canadensis* - *Juniperus virginiana* Forest (CEGL007240)
Low-Elevation Hardwood Forest	FAHC - Appalachian Herbaceous Cove Forest	*Aesculus flava* - *Acer saccharum* - (*Tilia americana* var. *heterophylla*) / *Hydrophyllum canadense* - *Solidago flexicaulis* Forest (CEGL007695)
	FAHC - Appalachian Herbaceous Cove Forest	*Liriodendron tulipifera* - *Fraxinus americana* - (*Aesculus flava*) / *Actaea racemosa* - *Laportea canadensis* Forest (CEGL007710)
Low-Elevation Mixed Deciduous-Conifer Forest	FOWP - Mixed Oak - White Pine Forest	*Pinus strobus* - *Quercus alba* - (*Carya tomentosa*) / *Gaylussacia ursina* Forest (CEGL007517)
	FOWP - Mixed Oak - White Pine Forest	*Pinus strobus* - *Quercus* (*coccinea*, *montana*) / (*Gaylussacia ursina*, *Vaccinium stamineum*) Forest (CEGL007519)
	FAEC - Appalachian Evergreen Shrub Cove Forest	*Pinus strobus* - *Tsuga canadensis* / *Rhododendron maximum* - (*Leucothoe fontanesiana*) Forest (CEGL007102)
	FAEC - Appalachian Evergreen Shrub Cove Forest	*Tsuga canadensis* / *Rhododendron maximum* - (*Clethra acuminata*, *Leucothoe fontanesiana*) Forest (CEGL007136)

Table B-2 (continued). Map-class codes and names, with crosswalk to vegetation types in the U.S. National Vegetation Classification for the Great Smoky Mountains National Park vegetation mapping project.

Map-class category	Map class	Vegetation type
Low-Elevation Mixed Deciduous-Conifer Forest (continued)	FAEC - Appalachian Evergreen Shrub Cove Forest	*Liriodendron tulipifera* - *Betula lenta* - *Tsuga canadensis* / *Rhododendron maximum* Forest (CEGL007543)
	FAEC - Appalachian Evergreen Shrub Cove Forest	*Tsuga canadensis* - *Halesia tetraptera* - *Magnolia fraseri* / *Rhododendron maximum* / *Dryopteris intermedia* Forest (CEGL007693)
Low-Elevation Pine Forest	FAWP - Southern Appalachian White Pine Forest	*Pinus strobus* / *Kalmia latifolia* - (*Vaccinium stamineum*, *Gaylussacia ursina*) Forest (CEGL007100)
Low-Elevation Pine Woodland	WYPO - Yellow Pine - (Dry Oak) Woodland	*Pinus virginiana* Ruderal Forest (CEGL002591)
	WYPO - Yellow Pine - (Dry Oak) Woodland	*Pinus echinata* / *Schizachyrium scoparium* Appalachian Woodland (CEGL003560)
	WYPO - Yellow Pine - (Dry Oak) Woodland	*Pinus virginiana* / *Vaccinium pallidum* / *Schizachyrium scoparium* - *Carex pensylvanica* Woodland (CEGL003624)
	WYPO - Yellow Pine - (Dry Oak) Woodland	*Pinus echinata* / *Vaccinium* (*pallidum, stamineum*) - *Kalmia latifolia* Forest (CEGL007078)
	WYPO - Yellow Pine - (Dry Oak) Woodland	*Pinus pungens* - *Pinus rigida* - (*Quercus montana*) / *Kalmia latifolia* - *Vaccinium pallidum* Woodland (CEGL007097)
	WYPO - Yellow Pine - (Dry Oak) Woodland	*Pinus virginiana* - *Pinus* (*rigida*, *echinata*) - (*Quercus montana*) / *Vaccinium pallidum* Forest (CEGL007119)
	WYPO - Yellow Pine - (Dry Oak) Woodland	*Pinus echinata* - *Quercus* (*montana*, *falcata*) / *Oxydendrum arboreum* / *Vaccinium pallidum* Forest (CEGL007493)
	WYPO - Yellow Pine - (Dry Oak) Woodland	*Pinus echinata* - *Quercus alba* / *Vaccinium pallidum* / *Hexastylis arifolia* - *Chimaphila maculata* Forest (CEGL008427)
	WYPO - Yellow Pine - (Dry Oak) Woodland	*Pinus virginiana* - (*Pinus rigida*, *Pinus pungens*) / *Schizachyrium scoparium* Forest (CEGL008500)

Table B-2 (continued). Map-class codes and names, with crosswalk to vegetation types in the U.S. National Vegetation Classification for the Great Smoky Mountains National Park vegetation mapping project.

Map-class category	Map class	Vegetation type
Floodplain Forest	FFMH - Mixed Hardwood Floodplain Forest	*Acer rubrum* var. *trilobum - Fraxinus pennsylvanica* / *Carex crinita - Peltandra virginica* Floodplain Forest (CEGL004420)
	FFMH - Mixed Hardwood Floodplain Forest	*Platanus occidentalis - Liriodendron tulipifera* - (*Betula alleghaniensis*) / *Alnus serrulata - Leucothoe fontanesiana* Floodplain Forest (CEGL004691)
	FFMH - Mixed Hardwood Floodplain Forest	*Tsuga canadensis - Liriodendron tulipifera - Platanus occidentalis* / *Rhododendron maximum - Xanthorhiza simplicissima* Wet Forest (CEGL007143)
	FFMH - Mixed Hardwood Floodplain Forest	*Platanus occidentalis - Fraxinus pennsylvanica - Quercus imbricaria* Floodplain Forest (CEGL007339)
	FFMH - Mixed Hardwood Floodplain Forest	*Liquidambar styraciflua - Liriodendron tulipifera* - (*Platanus occidentalis*) / *Halesia tetraptera* / *Amphicarpaea bracteata* Floodplain Forest (CEGL007880)
Wetland Forest	FUSP - Upland Sweetgum - Red Maple Pond	*Liquidambar styraciflua - Acer rubrum* / *Carex* spp. - *Sphagnum* spp. Seep Forest (CEGL007388)
Ruderal Deciduous Forest	FXSH - Southern Appalachian Ruderal Acidic Mixed Hardwood Forest	*Acer rubrum - Betula lenta - Magnolia fraseri* / (*Rhododendron maximum*, *Kalmia latifolia*) Ruderal Forest (CEGL008558)
	FXTW - Ruderal Tuliptree - Walnut Forest	*Liriodendron tulipifera - Acer negundo* Ruderal Forest (CEGL007184)
	FXTW - Ruderal Tuliptree - Walnut Forest	*Liriodendron tulipifera* / (*Cercis canadensis*) / (*Lindera benzoin*) Ruderal Forest (CEGL007220)
	FXTW - Ruderal Tuliptree - Walnut Forest	*Liriodendron tulipifera* - *Quercus* spp. Ruderal Forest (CEGL007221)
	FXTW - Ruderal Tuliptree - Walnut Forest	*Juglans nigra* / *Verbesina alternifolia* Ruderal Forest (CEGL007879)
	FXAH - Appalachian Ruderal Hardwood Forest	*Liriodendron tulipifera - Acer rubrum - Robinia pseudoacacia* Ruderal Forest (CEGL007219)
	FXBL - Ruderal Black Locust Forest	*Robinia pseudoacacia* Ruderal Forest (CEGL007279)
	FXSG - Ruderal Sweetgum Forest	*Liquidambar styraciflua* Ruderal Forest (CEGL007216)

Table B-2 (continued). Map-class codes and names, with crosswalk to vegetation types in the U.S. National Vegetation Classification for the Great Smoky Mountains National Park vegetation mapping project.

Map-class category	Map class	Vegetation type
Ruderal Conifer Forest	FXWP - Ruderal Eastern White Pine Forest	*Pinus strobus* Ruderal Forest (CEGL007944)
	FXNS - Ruderal Norway Spruce Forest	*Picea abies* Forest Plantation (CST007167)
High-Elevation Shrub & Herbaceous	SBMH - Southern Appalachian Mixed Heath Bald	*Kalmia latifolia - Rhododendron catawbiense* - (*Gaylussacia baccata*, *Pieris floribunda*, *Vaccinium corymbosum*) Shrubland (CEGL003814)
	SBMH - Southern Appalachian Mixed Heath Bald	*Leiophyllum buxifolium* Dwarf-shrubland (CEGL003951)
	SBMH - Southern Appalachian Mixed Heath Bald	*Rhododendron carolinianum - Rhododendron catawbiense - Leiophyllum buxifolium* Shrubland (CEGL007876)
	SDAB - Southern Appalachian Hybrid Deciduous Azalea Bald	*Rhododendron* (*calendulaceum*, *cumberlandense*) Appalachian Bald Shrubland (CEPS009759)
	SHBT - High-Elevation Blackberry Thicket	*Rubus allegheniensis - Rubus canadensis* / *Carex pensylvanica* Shrubland (CEGL003892)
	SHBT - High-Elevation Blackberry Thicket	*Rubus canadensis* - (*Rubus idaeus* ssp. *strigosus*) / *Athyrium filix-femina - Solidago glomerata* Shrubland (CEGL003893)
	SHBT - High-Elevation Blackberry Thicket	*Crataegus punctata - Crataegus flabellata* Ruderal Forest (CEGL004184)
	SHBT - High-Elevation Blackberry Thicket	(*Prunus pensylvanica*, *Sorbus americana*) - *Rubus* spp. Shrubland (CEGL007293)
	HGBF - Grassy Bald (Southern Grass Type)	*Danthonia compressa* - (*Sibbaldiopsis tridentata*) Grassland (CEGL004242)
	HSGF - Graminoid and Forb Rocky Summit	*Saxifraga michauxii - Carex misera - Oclemena acuminata - Solidago glomerata* Grassland (CEGL004277)
	HSGF - Graminoid and Forb Rocky Summit	*Saxifraga michauxii - Carex misera - Danthonia spicata - Krigia montana* Grassland (CEGL004279)
	HBAS - Southern Appalachian High-Elevation Rocky Summit (Anakeesta Type)	*Saxifraga michauxii - Carex misera - Calamagrostis cainii* Grassland (CEGL004278)

Table B-2 (continued). Map-class codes and names, with crosswalk to vegetation types in the U.S. National Vegetation Classification for the Great Smoky Mountains National Park vegetation mapping project.

Map-class category	Map class	Vegetation type
Low-Elevation Shrub & Herbaceous	SMRT - Montane Rhododendron Thicket	*Rhododendron maximum* Montane Ruderal Thicket (CEGL003819)
	SMRT - Montane Rhododendron Thicket	*Rhododendron maximum* / *Sphagnum* spp. Seepage Shrubland (CEGL003849)
	SGHO - Montane Grape Opening	*Vitis aestivalis* Vine-Scrub (CEGL003890)
	SFCB - Floodplain Canebrake	*Arundinaria gigantea* ssp. *gigantea* Wet Canebrake (CEGL003836)
	HLAG - Low-Elevation Acidic Glade (Grass Type)	(*Quercus montana*) / *Vaccinium pallidum* / *Schizachyrium scoparium* - *Danthonia spicata* / *Cladonia* spp. Scrub Grassland (CEGL004990)
Wetland Shrub & Herbaceous	SSAS - Southeastern Alder Swamp	*Alnus serrulata* Southeastern Seasonally Flooded Shrubland (CEGL008474)
	HXCR - Ruderal Common Rush Marsh	*Juncus effusus* Marsh (CEGL004112)
	HXCR - Ruderal Common Rush Marsh	*Juncus effusus* - *Chelone glabra* - *Scirpus* spp. Southern Blue Ridge Beaver Pond Ruderal Marsh (CEGL008433)
	HSCP - Smartweed - Cutgrass Beaver Pond	*Polygonum* (*hydropiperoides*, *punctatum*) - *Leersia* spp. Shoreline Wet Meadow (CEGL004290)
Ruderal Upland & Wetland Shrub & Herbaceous	SXBG - Ruderal Blackberry - Greenbrier Shrub Thicket	*Rubus* (*argutus*, *trivialis*) - *Smilax* (*glauca*, *rotundifolia*) Ruderal Shrubland (CEGL004732)
	SXBG - Ruderal Blackberry - Greenbrier Shrub Thicket	*Glyceria striata* - *Carex gynandra* - *Chelone glabra* - *Symphyotrichum puniceum* / *Sphagnum* spp. Herbaceous Seep (CEGL008438)
	SXKV - Ruderal Kudzu Vineland	*Pueraria montana* var. *lobata* Ruderal Vine-Shrubland (CEGL003882)
	HXFM - Grazed Montane Grassland / Fire Meadow	*Phleum pratense* - *Bromus pubescens* - *Helenium autumnale* Ruderal Meadow (CEGL004018)
	HXCM - Cultivated Grassland	*Schedonorus* (*arundinaceum*, *pratense*) Ruderal Grassland (CEGL004048)
	HXLD - Artificial Lake Drawdown Zone	(*Diospyros virginiana*, *Platanus occidentalis*) / *Eupatorium serotinum* - *Diodia virginiana* Ruderal Wet Meadow (CEGL003910)

Table B-2 (continued). Map-class codes and names, with crosswalk to vegetation types in the U.S. National Vegetation Classification for the Great Smoky Mountains National Park vegetation mapping project.

Map-class category	Map class	Vegetation type
Map-Special Vegetation	MSDH - Standing Dead Hemlock Forest	Standing Dead Hemlock Forest (Non-USNVC)
Cultural Vegetation	CFFP - Fraser Fir Plantation	Native Miscellaneous Southern Conifer Plantation (CST008544)
	CHAV - Herbaceous Agricultural Vegetation	Herbaceous Agricultural Vegetation (CSC02)
	CBRN - Barren Land	Herbaceous & Woody Developed Vegetation (CSC03)
	CDVL - Developed Land	Herbaceous & Woody Developed Vegetation (CSC03)
Rock	NRSL - Rock Slide	Barren Rock (Non-USNVC)
Water	NFPW - Flowing and Ponded Water	Open Water (Non-USNVC)

Page Reference to Map-Class Descriptions

Page Reference to Map-Class Descriptions (continued)

FBGP – Southern Appalachian Beech Gap

The Southern Appalachian Beech Gap (FBGP) map class represents the *Fagus grandifolia* / *Carex pensylvanica* - *Ageratina altissima* var. *roanensis* Forest Association (CEGL006130) in the USNVC. The forest association that makes up this map class only occurs in the highest elevation areas of the Park (higher than 1,400 m). The FBGP map class is rare within the Park covering 185.1 ha (0.1% of GRSM).

Almost exclusively dominated by short-statured or stunted and open-canopied American beech (*Fagus grandifolia*), the FBGP map class generally presents itself in the project imagery as a monotypic stand of leaf-off hardwoods slightly below the spruce-fir tree line. Occasionally, a beech clone would still have leaves that presents a very distinct and consistent signature of light pink, tan, or off white.

The AA results indicate that FBGP was mapped well with a users' accuracy of 90% and a producers' accuracy of 100%. The AA discloses one instance where FBGP was mapped too aggressively to the FNHH map class. This error centers around the misidentification of which northern hardwood tree species dominate the canopy.

An example of the FBGP map class showing the dominance of short-statured American beech (*Fagus grandifolia*).

FNHH – Northern Hardwood High-Elevation Forest

The Northern Hardwood High-Elevation Forest (FNHH) map class represents the following four associations in the USNVC:

- *Aesculus flava - Betula alleghaniensis - Acer saccharum* / *Caulophyllum thalictroides - Actaea podocarpa* Forest (CEGL004973),
- *Betula alleghaniensis - Tilia americana* var. *heterophylla* / *Acer spicatum* / *Ribes cynosbati* / *Dryopteris marginalis* Forest (CEGL004982),
- *Betula alleghaniensis* / *Ribes glandulosum* / *Polypodium appalachianum* Forest (CEGL006124), and
- *Betula alleghaniensis - Fagus grandifolia* / *Viburnum lantanoides* / *Eurybia chlorolepis - Dryopteris intermedia* Forest (CEGL007285).

This map class primarily represents forests dominated by northern hardwood tree species above 1,220 m elevation on the North Carolina side of the Park and above 1,160 m elevation on the Tennessee side. The forest associations that make up this map class occur throughout the upper elevations of the Park over most topographies, aspects, and soils. The FNHH map class is very common within the Park covering 13,483.7 ha (6.4% of GRSM).

Dominated by northern hardwood tree species, this map class senesced before other similar map classes in the high elevations and generally lost all leaf cover by the third GRSM imagery mission. This complete senescence helped to discern this map class from other similar hardwood tree map classes that retained some leaves later into the fall. Additionally, this map class had a general lack to absolute absence of tuliptree (*Liriodendron tulipifera*), helping to distinguish FNHH from its low-elevation counterpart FAHC.

The AA results indicate that FNHH was mapped well with a users' accuracy of 80% and a producers' accuracy of 86%. The AA discloses five instances where FNHH was mapped either too aggressively (to three map class) or too conservatively (from two map classes). These errors center around the misidentification of which northern hardwood tree species dominate the canopy (FXSH and FBGP), if northern hardwoods dominate the canopy (FHEO and FSHH), or if evergreen shrub dominates the shrub layer (FBHH).

Four examples of the FNHH map class showing CEGL004973 (upper left), CEGL004982 (upper right), CEGL006124 (lower left), and CEGL007285 (lower right). All examples show a northern hardwood canopy over different types of shrub and herb layers.

FHEO – High-Elevation Oak Forest

The High-Elevation Oak Forest (FHEO) map class represents the following four associations in the USNVC:

- *Quercus alba* / *Kalmia latifolia* Forest (CEGL007295),
- *Quercus rubra* / *Carex pensylvanica* - *Ageratina altissima* var. *roanensis* Forest (CEGL007298),
- *Quercus rubra* / (*Kalmia latifolia*, *Rhododendron catawbiense*, *Rhododendron maximum*) / *Galax urceolata* Forest (CEGL007299), and
- *Quercus rubra* / (*Vaccinium simulatum*, *Rhododendron calendulaceum*) / (*Dennstaedtia punctilobula*, *Thelypteris noveboracensis*) Forest (CEGL007300).

This map class primarily represents the highest elevation oak-dominated forests in the Park, consisting of northern red oak (*Quercus rubra*) and white oak (*Quercus alba*). The FHEO map class is very common within the Park covering 7,866.2 ha (3.7% of GRSM).

This oak dominated (generally greater than 50% and often greater than 75% of the canopy) map class is restricted to the highest elevations of the Park. The FHEO map class exists at an elevation above 1,220 m elevation on the North Carolina side of the Park and 1,160 m elevation on the Tennessee side. The signature in the project imagery and the landscape position of FHEO proved reliable because this map class exists on ridge and mountain tops only at higher elevations. The northern red oak and white oak in this map class generally present as crisp, tan-to-gold to pink-to-red broad-crowned canopy trees, but with canopy structure more open and smaller crowned than comparable oak at lower elevations. The oak may be intermixed with lighter-pink and white-crowned hardwood tree species, but never dominated.

The AA results indicate that FHEO was mapped well with a users' accuracy and producers' accuracy of 93%. The AA discloses only three instances where FHEO was mapped either too aggressively (to the FXSH map class) or too conservatively (from the FBHH and FNHH map classes). These errors were caused by the misestimation of non-oak hardwood tree canopy cover.

Four examples of the FHEO map class showing CEGL007295 with white oak (*Quercus alba*) over evergreen shrub (upper left), CEGL007298 with northern red oak (*Quercus rubra*) over herb, CEGL007299 with northern red oak over evergreen shrub (lower left), and CEGL007300 with northern red oak over deciduous shrub (lower right). All examples are at high elevations (over 1,220 m).

FBHH – Blue Ridge Hemlock - Northern Hardwood Forest

The Blue Ridge Hemlock - Northern Hardwood Forest (FBHH) map class represents the *Betula alleghaniensis* - (*Tsuga canadensis*) / *Rhododendron maximum* / (*Leucothoe fontanesiana*) Forest Association (CEGL007861) in the USNVC. The forest association that makes up this map class is confined to the higher elevations of the Park. The FBHH map class is very common within the Park covering 21,340.0 ha (10.1% of GRSM).

Dominated by yellow birch (*Betula alleghaniensis*) and other northern hardwoods over a thick shrub layer of great laurel (*Rhododendron maximum*), the canopy of FBHH was historically mixed with eastern hemlock (*Tsuga canadensis*). During the past 15-years, various non-native insects nearly eliminated eastern hemlock in the Park except for areas actively treated to preserve this tree species. Consequently, the FBHH map class no longer contains more than a pittance of the eastern hemlock that CEGL007861 once had. This map class, at the time of this mapping project, generally presents as a northern hardwood forest over a thick evergreen shrub layer above 1,220 m elevation on North Carolina side of the Park and above 1,160 m elevation on the Tennessee side. The FBHH map class generally is intermixed with the FNHH and FHEO map classes, but FBHH lacks the oaks of FHEO and has the evergreen shrub layer that FNHH lacks.

The AA results indicate that FBHH was mapped with a users' accuracy of 60% (90% confidence interval of 44–76%) and a producers' accuracy of 95%. The AA discloses many instances where FBHH was mapped too aggressively (to seven map classes) and only one instance where FBHH was mapped too conservatively. In almost all instances, the errors resulted from one of the following three causes: underestimating oak cover (FCES and FHEO), misinterpreting the shrub cover (FAHC and FNHH), or underestimating spruce cover (FSHE and FSHH). The underestimation of spruce cover (FSHE and FSHH) accounted for one-half of the errors in users' accuracy; however, the underestimation error was not chronic in either the users' accuracy or the producers' accuracy.

The 90% confidence interval for the users' accuracy remains below the standard. Decisions with GRSM staff resulted in accepting a slightly lower users' accuracy for the FBHH map class instead of merging more map classes together to boost accuracy results. Information on this decision is reported in "Appendix D: Accuracy Assessment Reconciliation."

An example of the FBHH map class showing the characteristically northern hardwood canopy over great laurel (*Rhododendron maximum*). Note the large dead eastern hemlock (*Tsuga canadensis*) center with scattered remnant, treated eastern hemlock located right and center on the image.

FSHE – Red Spruce - Northern Hardwood Forest (Shrub Type)

The Red Spruce - Northern Hardwood Forest (Shrub Type) (FSHE) map class represents the *Picea rubens* - (*Betula alleghaniensis*, *Aesculus flava*) / *Rhododendron* (*maximum*, *catawbiense*) Forest Association (CEGL004983) in the USNVC. The forest association that makes up this map class only occurs within the higher reaches (above 1,300 m elevation) of the Park. The FSHE map class is very common within the Park covering 6,255.7 ha (3.0% of GRSM).

Dominated by a mix of red spruce (*Picea rubens*) and northern hardwoods, particularly yellow birch (*Betula alleghaniensis*), the FSHE map class occurs as the transitional forest between the lower-elevation hardwood-dominated forests and the higher-elevation conifer-dominated forests. The FSHE map class is defined by the presence of an evergreen shrub layer and was common along the backbone of the Smoky Mountains. In the project imagery, FSHE presents as a mixed spruce-hardwood canopy forest with a broken to open canopy showing the red glow of an evergreen shrub layer. The assumption was that an evergreen shrub layer either would be visible through the canopy gaps or unable to persist under a closed canopy.

The AA results indicate that FSHE was mapped with a users' accuracy of 83% (90% confidence interval of 62–88%) and a producers' accuracy of 76% (90% confidence interval of 62–90%). The AA discloses two instances where FSHE was mapped too aggressively and four instances where FSHE was mapped too conservatively. These errors primarily result from a misestimation of evergreen shrub cover, from a misestimation of northern hardwood and red spruce cover, and from one instance of overestimation of yellow pine coverage.

An example of the FSHE map class showing the characteristic canopy of mixed red spruce (*Picea rubens*) and northern hardwoods over a dense evergreen shrub layer.

FSHH – Red Spruce - Northern Hardwood Forest (Herb Type)

The Red Spruce - Northern Hardwood Forest (Herb Type) (FSHH) map class represents the *Picea rubens* - (*Betula alleghaniensis*, *Aesculus flava*) / *Viburnum lantanoides* / *Solidago glomerata* Forest Association (CEGL006256) in the USNVC. The forest association that makes up this map class only occurs within the higher reaches (above 1,300 m elevation) of the Park. The FSHH map class is very common within the Park covering 5,699.7 ha (2.7% of GRSM).

Dominated by a mix of red spruce (*Picea rubens*) and northern hardwoods, particularly yellow birch (*Betula alleghaniensis*), the FSHH map class occurs as the transitional forest between the lower-elevation hardwood-dominated forests and higher-elevation conifer-dominated forests. This map class is common along the backbone of the Smoky Mountains. In the project imagery, FSHH presents as a mixed spruce-hardwood canopy forest with a closed, dense canopy. The assumption was that an evergreen shrub layer either would be visible through the canopy gaps or unable to persist under a closed canopy.

The AA results indicate that FSHH was mapped with a users' accuracy of 90% and a producers' accuracy of 60% (90% confidence interval of 47–73%). The AA discloses two instances where FSHH was mapped aggressively and many instances where FSHH was mapped too conservatively (from six map classes). These errors originate from some combination of misestimation of conifer canopy cover, misidentification of an evergreen shrub layer, and underestimation of total canopy cover.

The 90% confidence interval for the producers' accuracy remains below the standard. Decisions with GRSM staff resulted in accepting a lower producers' accuracy for the FSHH map class instead of merging more map classes together to boost accuracy results. Information on this decision is in "Appendix D: Accuracy Assessment Reconciliation."

Two examples of the FSHH map class showing the mixed spruce-northern hardwood canopy over a dense deciduous shrub layer, generally with a more open canopy (left) and a sparse shrub layer, generally with a more closed canopy (right).

FFFS – Fraser Fir / Mixed Shrub Forest

The Fraser Fir / Mixed Shrub Forest (FFFS) map class represents two associations in the USNVC—the *Abies fraseri* / *Viburnum lantanoides* / *Dryopteris campyloptera* - *Oxalis montana* / *Hylocomium splendens* Forest (CEGL006049) and the *Abies fraseri* / (*Rhododendron catawbiense*, *Rhododendron carolinianum*) Forest (CEGL006308). The forest associations that make up this map class only occur in the highest reaches (above 1,830 m elevation) of the Park and are limited to small areas. The FFFS map class is uncommon within the corridor covering 279.7 ha (0.1% of GRSM).

Dominated by Fraser fir (*Abies fraseri*), the FFFS map class generally presents as a monotypic stand of fir or fir mixed with sparse red spruce (*Picea rubens*). Present above the spruce-dominated forest downslope, this map class tends to cover the peaks of the highest mountains in the Park. In the project imagery, the ability to split the two associations apart was investigated, but the visibility of the shrub layer, either evergreen or deciduous, was unreliable. Generally, the Fraser fir in FFFS tend to present a redder, more robust signature than the spruce because of the flatter and more horizontal plane of Fraser fir leaves, with the overall effect being a dense red-conifer forest.

The AA results indicate that FFFS was mapped with a users' accuracy of 73% (90% confidence interval of 58–88%) and a producers' accuracy of 96%. The AA discloses two instances where FFFS was mapped too aggressively and one instance where FFFS was mapped too conservatively. In all instances, the errors come from the confusion with co-occurring high-elevation red spruce map classes and the misidentification of spruce versus fir. Most of this confusion was because of a consistent overestimation of Fraser fir cover in the FSFD map class.

Two examples of the FFFS map class showing the sparse deciduous shrub layer of CEGL006049 (left) and the dense evergreen shrub layer of CEGL006308 (right), both aspects are under a canopy of Fraser fir (*Abies fraseri*).

FSFD – Red Spruce - Fraser Fir Forest (Deciduous Shrub Type)

The Red Spruce - Fraser Fir Forest (Deciduous Shrub Type) (FSFD) map class represents the *Picea rubens* - (*Abies fraseri*) / *Vaccinium erythrocarpum* / *Dryopteris campyloptera* / *Hylocomium splendens* Forest Association (CEGL007131) in the USNVC. The forest association that makes up this map class only occurs within the higher reaches (above 1,400 m elevation) of the Park. The FSFD map class is common within the Park covering 2,287.0 ha (1.1% of GRSM).

Dominated by a mix of red spruce (*Picea rubens*) and Fraser fir (*Abies fraseri*), the FSFD map class can occur over any type of understory (including spruce and fir regeneration), with the exception of evergreen shrub. Present above the hardwood dominated lower slopes, this map class generally occurs along the backbone of the Smoky Mountains. In the project imagery, FSFD presents as a mixed spruce-fir canopy forest either with a closed canopy or an open canopy that lacked an evergreen shrub layer. The assumption was that an evergreen shrub layer either would be visible through the canopy gaps or unable to persist under a closed canopy.

The AA results indicate that FSFD was mapped with a users' accuracy of 70% (90% confidence interval of 55–85%) and a producers' accuracy of 68% (90% confidence interval of 52–83%). The AA discloses several instances where FSFD was mapped either too aggressively (to two map classes) or too conservatively (from four map classes). In all instances (users' and producers') the errors come from the confusion with co-occurring mixed red spruce - Fraser fir forest map classes where either the shrub and herb layers were misinterpreted or the dominance of fir was overestimated.

An example of the FSFD map class showing a very sparse understory below a dense spruce-fir canopy.

FSFE – Spruce - Fir / Evergreen Shrub Forest

The Spruce - Fir / Evergreen Shrub Forest (FSFE) map class represents two associations in the USNVC—the *Picea rubens* - (*Tsuga canadensis*) / *Rhododendron maximum* Forest (CEGL006152) and the *Picea rubens* - (*Abies fraseri*) / (*Rhododendron catawbiense*, *Rhododendron maximum*) Forest (CEGL007130). The forest associations that make up this map class only occur within the higher reaches (above 1,400 m elevation) of the Park. The FSFE map class is common within the Park covering 2,089.7 ha (1.0% of GRSM).

Dominated by a mix of red spruce (*Picea rubens*) and Fraser fir (*Abies fraseri*), the FSFE map class can only occur over an understory of evergreen shrub (this does not include spruce and fir regeneration). Present above the hardwood dominated lower slopes, this map class is common along the backbone of the Smoky Mountains. In the project imagery, FSFE presents as a mixed spruce-fir canopy forest with an open canopy showing a consistent red glow from a dense evergreen shrub layer. The assumption was that an evergreen shrub layer either would be visible through the canopy gaps or unable to persist under a closed canopy.

The AA results indicate that FSFE was mapped well with a users' accuracy of 80% and a producers' accuracy of 86%. The AA discloses five instances where FSFE was mapped either too aggressively (to four map classes) or too conservatively (from the FSFD map class). One-half of the errors (users' and producers'), come from confusion with the FSFD map class. The confusion was caused by misinterpretation of whether the shrub and herb layer was evergreen (for FSFE) or deciduous (for FSFD). The remaining errors come from the misestimation of either Fraser fir cover or northern hardwood cover.

Two examples of the FSFE map class showing a CEGL006152 with large red spruce (*Picea rubens*) with standing-dead eastern hemlock (*Tsuga canadensis*) over rhododendron species (*Rhododendron* spp.) (left) and a CEGL007130 with red spruce and Fraser fir (*Abies fraseri*) over rhododendron (right). Both examples have an open canopy that supports persistence of the evergreen shrub layer.

WTMH – Blue Ridge Table Mountain Pine - Pitch Pine Woodland (High-Elevation Type)

The Blue Ridge Table Mountain Pine - Pitch Pine Woodland (High-Elevation Type) (WTMH) map class represents the *Pinus rigida* - (*Pinus pungens*) / *Rhododendron catawbiense* - *Kalmia latifolia* / *Galax urceolata* Woodland Association (CEGL004985) in the USNVC. In the Park, this map class represents a Table Mountain pine (*Pinus pungens*) woodland or open forest with an evergreen heath shrub layer above 1,220 m elevation. The WTMH map class is rare within the Park covering 159.6 ha (0.1% of GRSM).

The WTMH map class is defined by Table Mountain pine and occasionally pitch pine (*Pinus rigida*) dominated sites on hot and dry topographic positions above 1,220 m elevation. Occasionally, hardwood tree species, such as red maple (*Acer rubrum*), adapted to dry, acidic sites and codominated, but never dominated, the canopy with the pines. In the project imagery, WTMH generally presents as an open canopy of dark-pink to purple, small and tight crowned conifers over a bright-red layer of evergreen heath shrub.

The AA results indicate that WTMH was mapped well with a users' accuracy of 90% and a producers' accuracy of 100%. The AA discloses two instances where WTMH was mapped too aggressively to the FSHE and SBMH map classes. These errors were caused by underestimating red spruce (*Picea rubens*) cover in the canopy and by overestimating total pine cover in the canopy.

An example of the WTMH map class showing CEGL004985 with a very dense evergreen heath shrub layer with, scarcely visible, an open Table Mountain pine (*Pinus pungens*) canopy.

FCES – Chestnut Oak / Evergreen Shrub Forest

The Chestnut Oak / Evergreen Shrub Forest (FCES) map class represents the following four associations in the USNVC:

- *Quercus* (*montana*, *coccinea*) / *Kalmia latifolia* / (*Galax urceolata*, *Gaultheria procumbens*) Forest (CEGL006271),
- *Quercus montana - Quercus rubra* / *Rhododendron maximum* / *Galax urceolata* Forest (CEGL006286),
- *Quercus alba - Quercus coccinea - Quercus falcata* / *Kalmia latifolia - Vaccinium pallidum* Forest (CEGL007691), and
- *Quercus montana* - (*Quercus coccinea*) / *Carya pallida* / *Vaccinium arboreum - Vaccinium pallidum* Forest (CEGL008431).

This map class represents a diverse mix of primarily dry, chestnut oak (*Quercus montana*) dominated forest over a layer of sparse-to-impenetrable evergreen shrub present across a wide range of elevation (generally below 1,525 m). The FCES map class is the most common map class in the Park covering 59,794.6 ha (28.4% of GRSM).

The FCES map class is an oak-dominated (generally greater than 40% canopy, often greater than 75% canopy) forest with varying amounts of hickory species (*Carya* spp.) and hardwoods and occasional (less than 25% canopy) pine species (*Pinus* spp.) over a heath shrub layer that generally is evergreen, but also can be deciduous or mixed evergreen-deciduous. Extensively covering dry-mesic and hot, dry slopes and ridgetops, this map class also will creep around to cooler, more sheltered slopes where little soil exists to maintain moisture in the forest. In the project imagery, the oak in the FCES map class generally presents as crisp, tan, pink, and red, small-to-medium-crowned, open-to-closed-canopy trees. These canopy trees may or may not be intermixed with lighter pink, orange, yellow, and white-crowned hickory and hardwoods with smaller crowns. Occasionally, in the hottest, driest locations, this forest presents a very sparse and short-statured canopy over dense and tall evergreen shrub as the forest trends towards a heath bald community. This presentation contrasts directly with the more mesic topographic position, dark color, and larger more closed canopy associated with FOHM.

The AA results indicate that FCES was mapped with a users' accuracy of 68% (90% confidence interval of 53–82%) and a producers' accuracy of 47% (90% confidence interval of 34–60%). The AA discloses several instances where FCES was mapped either too aggressively (to four map classes) or too conservatively (from nine map classes). Most of the users' errors relate to confusion with the co-occurring FOHM oak forest map classes. The producers' errors indicate confusion with the co-occurring FOHM oak forest map classes, an overly conservative estimation of oak cover in a dryer hardwood forest map classes (FXSH), and then an overly conservative estimation of oak canopy in shrub classes.

The 90% confidence interval for the users' accuracy remains below the standard. Decisions with GRSM staff resulted in accepting a slightly lower producers' accuracy for the FCES map class

instead of merging more map classes together to boost accuracy results. Information on this decision is reported in “Appendix D: Accuracy Assessment Reconciliation.”

Four examples of the FCES map class showing CEGL006271 with an open, short canopy over an evergreen shrub layer (upper left), CEGL006286 with a dense and tall evergreen shrub layer (upper right), CEGL007691with a mixed evergreen and deciduous shrub layer (lower left), and CEGL008431 with a deciduous heath layer (lower right). All examples are under a chestnut oak (*Quercus montana*) canopy.

FOHM – Mixed Oak / Mixed Shrub and Herb Forest

The Mixed Oak / Mixed Shrub and Herb Forest (FOHM) map class represents the following seven associations in the USNVC:

- *Quercus rubra - Acer rubrum* / *Pyrularia pubera* / *Thelypteris noveboracensis* Forest (CEGL006192),
- *Quercus alba - Quercus* (*rubra*, *montana*) / *Rhododendron calendulaceum* - (*Gaylussacia ursina*) Forest (CEGL007230),
- *Quercus montana* - (*Quercus rubra*) - *Carya* spp. / *Oxydendrum arboreum - Cornus florida* Forest (CEGL007267),
- *Quercus alba - Quercus rubra - Quercus montana* / *Collinsonia canadensis - Podophyllum peltatum* Forest (CEGL007692),
- *Quercus montana - Juniperus virginiana* - (*Pinus virginiana*) / *Philadelphus hirsutus - Celtis occidentalis* Woodland (CEGL007720),
- *Quercus rubra - Tilia americana* var. *heterophylla* - (*Halesia tetraptera* var. *monticola*) / *Collinsonia canadensis - Prosartes lanuginosa* Forest (CEGL007878), and
- *Quercus alba - Quercus falcata* / *Vaccinium* (*arboreum*, *hirsutum*, *pallidum*) Forest (CEGL008567).

This map class represents the very diverse northern red and white oak (*Quercus rubra and Quercus alba*) dominated forests and chestnut oak (*Quercus montana*) over deciduous shrub and herb forest in the Park. The FOHM map class is very common within the Park covering 24,708.5 ha (11.7% of GRSM).

The FOHM map class was originally a complex mix of low-elevation mesic to dry-mesic northern red oak and white oak dominated forests; however, during the AA process, consistent confusion was evident with the FCDS map class. The FCDS map class was a mesic, deciduous shrub chestnut oak map class. Because of the degree of overlap determined during AA, these two map classes merged to form a dry-mesic to mesic mixed-oak, mixed-shrub, and herb map class spanning most of the middle elevations having nonevergreen-heath and non-heath oak habitats in the Park. Information on the decision to merge original FCDS and FOHM map classes is in "Appendix D: Accuracy Assessment Reconciliation."

The signature in the project imagery and the landscape position of FOHM proved reliable because this map class exists on lower and mid-slopes in mesic to dry-mesic positions below 1,220 m elevation. These oak forests generally present a crisp, bright-pink to darker-pink to red and broad-crowned canopy representing the oaks. These forests are intermixed with russet- and orange-crowned oaks, yellow-crowned hickory species (*Carya* spp.), and various hardwood tree species. This presentation contrasts directly with the drier topographic position, lighter color, and smaller more diffuse crowns associated with FCES.

The AA results indicate that FOHM was mapped with a users' accuracy of 85% and a producers' accuracy of 71% (90% confidence interval of 62–80%). The AA discloses several instances where

FOHM was mapped too aggressively (to three map classes) and many instances where FOHM was mapped too conservatively (from seven map classes). Most of the errors come from confusion with the FCES map class because evergreen shrub cover was misinterpreted. Other sources of error include misestimation of non-oak hardwood tree cover and misinterpretation of elevational changes with the high-elevation FHEO map class.

Four examples of the FOHM map class showing CEGL006192 with northern red oak (*Quercus rubra*) over deciduous shrubs (upper left), CEGL007230 with white oak (*Quercus alba*) over deciduous heath (upper right), CEGL007878 with northern red oak over an enriched herb layer (lower left), and CEGL008567 with northern red oak over a deciduous heath layer (lower right). All examples show large oak with a closed canopy below 1,220 m elevation.

FROH – Ridge-and-Valley Oak - Hardwood Forest

The Ridge-and-Valley Oak - Hardwood Forest (FROH) map class represents two associations in the USNVC—the *Quercus alba - Quercus rubra - Carya ovalis / Acer saccharum / Polystichum acrostichoides* Forest (CEGL007233) and the *Quercus alba - Quercus rubra - Carya ovata / Cercis canadensis - Juniperus virginiana* Forest (CEGL007240). The forest associations that make up this map class only occur on the enriched soils in the very north of the Park along the Foothills Parkway. The FROH map class is extremely rare within the Park covering only 16.9 ha (0.008% of GRSM).

Dominated by white oak (*Quercus alba*) and mixed hardwoods including hickory species (*Carya* spp.) over an enriched herbaceous and shrub layer, the FROH map class was on dry-mesic moderate to steep slopes at the lowest elevations in the Park (below 800 m elevation), specifically within the Foothills Parkway of GRSM. Initially, only the association CEGL007240 defined this map class; however, during the AA process, several sites were determined to not fit well with CEGL007240, but instead with CEGL007233. The Park staff and classifier determined that CEGL007233, originally associated with the FOHM map class, was better defined by and represented in the FROH map class and, therefore, was moved to the FROH map class. The association CEGL007233 could potentially still overlap with the FOHM map class because CEGL007233 was noted in the Cades Cover area, but this overlap is limited to a small area.

The AA results indicate that FROH was mapped with a users' accuracy of 64% (90% confidence interval of 35–92%) and a producers' accuracy of 78% (90% confidence interval of 49–106%). Because of the rarity of this map class within the Park, the number of potential AA sites was restricted; thus, resulting in a wide range in confidence intervals. The AA discloses a few instances where FROH was mapped either too aggressively (to the FOHM and FXTW map classes) or too conservatively (from the FOHM map class). These errors were caused by misestimation of northern red oak (*Quercus rubra*) cover or underestimation of tuliptree (*Liriodendron tulipifera*) cover.

Two examples of the FROH map class showing a CEGL007233 with white oak (*Quercus alba*) and mixed hardwoods (left) and a CEGL007240 with white oak and hickory species (*Carya* spp.) (right), both views are over an enriched shrub and herb layer.

FAHC – Appalachian Herbaceous Cove Forest

The Appalachian Herbaceous Cove Forest (FAHC) map class represents two associations in the USNVC—the *Aesculus flava* - *Acer saccharum* - (*Tilia americana* var. *heterophylla*) / *Hydrophyllum canadense* - *Solidago flexicaulis* Forest (CEGL007695) and the *Liriodendron tulipifera* - *Fraxinus americana* - (*Aesculus flava*) / *Actaea racemosa* - *Laportea canadensis* Forest (CEGL007710). The forest associations that make up this map class occur in typic and enriched topographically sheltered locations throughout the Park. The FAHC map class is very common within the corridor covering 8,793.7 ha (4.2% of GRSM).

The FAHC map class presents a variable signature depending on which mesophytic tree species dominate the site, but generally tuliptree (*Liriodendron tulipifera*) codominates to dominates any given site. Additionally, sites are generally not even-aged and have very diverse crown morphology. The landscape position of FAHC is always sheltered and below 1,070 m elevation on the North Carolina side of the Park and below 915 m elevation on Tennessee side with very few instances of the map class ranging above 1,220 m elevation. In the project imagery, generally the tuliptree in FAHC present as a pink (sometimes white, orange, or red) conical (except in very large individuals where the crown becomes broken) tree with the other mesophytic hardwoods being purples, oranges, and reds. The herb layer is generally not visible, but the shrub layer is obviously not evergreen.

The AA results indicate that FAHC was mapped well with a users' accuracy and producers' accuracy of 83%. The AA discloses five instances where FSHH was mapped either too aggressively (to three map classes) or too conservatively (from the four map classes). These errors come from the misestimation of tuliptree cover (FXSH, FBGP, and FOHM), whether the vegetation was sufficiently mature or still ruderal (FXSH and FXTW), or whether evergreen shrub dominates the shrub layer (FAEC and FBHH).

Two examples of the FAHC map class showing CEGL007695 (left) and CEGL007710 (right). Both examples show a mesophytic hardwood tree canopy over a verdant and diverse herb layer.

FOWP – Mixed Oak - White Pine Forest

The Mixed Oak - White Pine Forest (FOWP) map class represents two associations in the USNVC—the *Pinus strobus* - *Quercus alba* - (*Carya tomentosa*) / *Gaylussacia ursina* Forest (CEGL007517) and the *Pinus strobus* - *Quercus* (*coccinea*, *montana*) / (*Gaylussacia ursina*, *Vaccinium stamineum*) Forest (CEGL007519). The forest associations that make up this map class primarily represent eastern white pine (*Pinus strobus*) - mixed oak species (*Quercus* spp.) forests in the Park. The FOWP map class is very common within the Park covering 5,908.8 ha (2.8% of GRSM).

The FOWP map class is present on a variety of aspects, slopes, and topographic positions below 1,200 m elevation. Codominated (each 25–75% canopy cover) by emergent (often super canopy) eastern white pine and by mixed oaks, FOWP is very distinctive in the project imagery; the eastern white pine presents as broad and diffusely branching dark-purple canopies and the mixed oaks as crisp, tan, orange, and pink broad-crowned canopies.

The AA results indicate that FHWO was mapped well with a users' accuracy of 77% (90% confidence interval of 62–92%) and a producers' accuracy of 79% (90% confidence interval of 65–93%). The AA discloses several instances where FOWP was mapped either too aggressively (to three map classes) or too conservatively (from four map classes). The errors consisted of misestimation of oak, yellow pine, or eastern white pine cover and the rare overestimation of the degree of disturbance.

Two examples of the FOWP map class showing a CEGL007517 with white oak (*Quercus alba*) and eastern white pine (*Pinus strobus*) over heath (left) and a CEGL007519 with chestnut oak (*Quercus montana*) and eastern white pine over heath (right).

FAEC – Appalachian Evergreen Shrub Cove Forest

The Appalachian Evergreen Shrub Cove Forest (FAEC) map class represents the following four associations in the USNVC:

- *Pinus strobus - Tsuga canadensis* / *Rhododendron maximum* - (*Leucothoe fontanesiana*) Forest (CEGL007102),
- *Tsuga canadensis* / *Rhododendron maximum* - (*Clethra acuminata*, *Leucothoe fontanesiana*) Forest (CEGL007136),
- *Liriodendron tulipifera - Betula lenta - Tsuga canadensis* / *Rhododendron maximum* Forest (CEGL007543), and
- *Tsuga canadensis - Halesia tetraptera - Magnolia fraseri* / *Rhododendron maximum* / *Dryopteris intermedia* Forest (CEGL007693).

This map class represents hardwood and mixed mesic hardwood-evergreen forests found in topographic coves over evergreen shrubs. The FAEC map class is very common within the Park covering 19,936.1 ha (9.5% of GRSM).

Originally conceived as two separate map classes representing low-elevation mesic hardwood coves (CEGL007543 and CEGL007693) and low-elevation mesic evergreen coves (CEGL007102 and CEGL007136), the AA indicated consistent and significant confusion between the two map classes. The confusion stems from how forests have changed following eastern hemlock (*Tsuga canadensis*) mortality and how much eastern white pine can exist in CEGL007543, making an overlap of signatures in the project imagery. Information on the decision to merge the two map classes is in "Appendix D: Accuracy Assessment Reconciliation." Additionally, forests formerly dominated by eastern hemlock could have succeeded to this map class from the MSDH map class as young hardwood trees mature in the formerly evergreen coves.

The cove forests of the southern Appalachian Mountains are some of the most biologically diverse ecosystems in the coterminous United States. Although generally dominated by hardwoods, this map class also can contain as much as 75% canopy cover of eastern white pine (*Pinus strobus*) and eastern hemlock (only where treated); however, this canopy cover is exceptionally uncommon. Crown morphology is similarly variable with many different shapes and textures with colors in the project imagery of red, orange, yellow, tan, pink, and white commonly intermix; however, monotypic stands are common, especially of tuliptree (*Liriodendron tulipifera*). Oaks are generally absent from this map class. Topographic position is very indicative for this map class especially in sheltered locations favoring the mesophytic cove forests of this map class. Generally found below 1,070 m elevation on the North Carolina side of the Park and below 915 m elevation on the Tennessee side, this map class can be occasionally above 1,220 m elevation.

The AA results indicate that FAEC was mapped with a users' accuracy of 63% (90% confidence interval of 50–77%) and a producers' accuracy of 72% (90% confidence interval of 59–86%). The AA discloses many instances where FAEC was mapped either too aggressively (to eight map classes) or too conservatively (from five map classes). In almost all instances, the errors resulted from one of the following three causes: misinterpreting where the edge of the topographic cove was (FCDS

FCES, FOHM, and WYPO), misinterpreting the shrub cover (FAHC and FFMH), or misinterpreting ruderal from non-ruderal map classes (FXAH and FXTW). In one instance (FXWP map class), the users' accuracy and producers' accuracy had many errors that were caused by underestimating the evergreen tree cover and the degree of disturbance. However, after consultation with Park staff, the errors were accepted in the interest of keeping the more ruderal vegetation of FXWP out of the non-ruderal FAEC.

The 90% confidence interval for the users' accuracy remains below the standard. Decisions with GRSM staff resulted in accepting a slightly lower producers' accuracy for the FAEC map class instead of merging more map classes together to boost accuracy results. Information on this decision is in "Appendix D: Accuracy Assessment Reconciliation."

Four examples of the FAEC map class showing CEGL007102 (upper left), CEGL007136 (upper right), CEGL007543 (lower left), and CEGL007693 (lower right). All examples show a closed non-northern hardwood canopy over a thick evergreen shrub layer.

FAWP – Southern Appalachian White Pine Forest

The Southern Appalachian White Pine Forest (FAWP) map class represents the *Pinus strobus* / *Kalmia latifolia* - (*Vaccinium stamineum*, *Gaylussacia ursina*) Forest Association (CEGL007100) in the USNVC. The forest association that makes up this map class occurs widely scattered throughout the Park below 1,000 m elevation. The FAWP map class is extremely rare within the Park covering only 20.0 ha (0.009% of GRSM).

This eastern white pine (*Pinus strobus*) dominated map class is generally found in isolated locations and on steep slopes that escaped logging. In the project imagery, FAWP presents as a forest that is very tall statured having a bright-purple star-shaped super-canopy of eastern white pine over smaller eastern white pine and mixed hardwoods. This presentation contrasts from the monoculture of dense, shorter eastern white pine in locations with a history of significant disturbance that defines the FXWP map class.

The AA results indicate that FAWP was mapped with a users' accuracy of 67% (90% confidence interval of 35–98%) and a producers' accuracy of 60% (90% confidence interval of 30–90%). The AA discloses two instances where FAWP was mapped too aggressively (to two map classes) and two instances where FAWP was mapped too conservatively (from two map classes). Most of the errors come from confusion with the FOWP map class because the amount of eastern white pine was misestimated. Other sources of error include overestimation of the amount of pine in the canopy and overestimation of the amount of disturbance.

An example of the FAWP map class showing the large, mature eastern white pine (*Pinus strobus*) dominated canopy over an evergreen shrub layer.

WYPO – Yellow Pine - (Dry Oak) Woodland

The Yellow Pine - (Dry Oak) Woodland (WYPO) map class represents the following nine associations in the USNVC:

- *Pinus virginiana* Ruderal Forest (CEGL002591),
- *Pinus echinata* / *Schizachyrium scoparium* Appalachian Woodland (CEGL003560),
- *Pinus virginiana* / *Vaccinium pallidum* / *Schizachyrium scoparium* - *Carex pensylvanica* Woodland (CEGL003624),
- *Pinus echinata* / *Vaccinium* (*pallidum*, *stamineum*) - *Kalmia latifolia* Forest (CEGL007078),
- *Pinus pungens* - *Pinus rigida* - (*Quercus montana*) / *Kalmia latifolia* - *Vaccinium pallidum* Woodland (CEGL007097),
- *Pinus virginiana* - *Pinus* (*rigida*, *echinata*) - (*Quercus montana*) / *Vaccinium pallidum* Forest (CEGL007119),
- *Pinus echinata* - *Quercus* (*montana*, *falcata*) / *Oxydendrum arboreum* / *Vaccinium pallidum* Forest (CEGL007493),
- *Pinus echinata* - *Quercus alba* / *Vaccinium pallidum* / *Hexastylis arifolia* - *Chimaphila maculata* Forest (CEGL008427), and
- *Pinus virginiana* - (*Pinus rigida*, *Pinus pungens*) / *Schizachyrium scoparium* Forest (CEGL008500).

This map class represents a mix of dry (yellow) pine woodland and open forest mixed with occasional dry oak species (*Quercus* spp.) found commonly throughout the Park on dry and exposed sites below 1,220 m elevation. The WYPO map class is very common within the Park covering 9,268.1 ha (4.4% of GRSM).

The WMDP map class is defined by Virginia, Table Mountain, short leaf, and pitch pine (*Pinus virginiana*, *Pinus pungens*, *Pinus echinata*, and *Pinus rigida*, respectively), commonly called yellow pine, dominated sites (usually greater than 50% relative cover of pine trees to hardwood trees, but as little as 25% cover) on hot or dry and often steep topographic positions. Often, hardwood tree species adapted to dry, acidic sites, such as red maple (*Acer rubrum*), blackgum (*Nyssa sylvatica*), sourwood (*Oxydendrum arboreum*), and scarlet and chestnut oak (*Quercus coccinea* and *Quercus montana*) codominated, but never dominated the canopy with the yellow pine. Although the WMDP map class was most common below 1,000 m elevation, the map class could be found on north-facing step slopes with very shallow soils. In the project imagery, WYPO generally presents as an open canopy of dark-pink to purple, small and tight crowned conifers intermixed with white, tan, and, occasionally, orange and yellow fluffy crowned hardwood trees and often over a bright-red layer of evergreen heath shrub.

The AA results indicate that WYPO was mapped well with a users' accuracy of 86% and a producers' accuracy of 84%. The AA discloses several instances where WYPO was mapped too aggressively (to four map classes) and too conservatively (from four map classes). These errors were

caused by confusion of eastern white pine (*Pinus strobus*) with yellow pine, misestimating yellow pine and oak cover in the canopy, and by overestimating total yellow pine cover in the canopy.

Four examples of the WYPO map class showing CEGL002591 (upper left), CEGL007097 (upper right), CEGL007119 (lower left), and CEGL008427 (lower right). All examples show an open to closed canopy of yellow pine species (*Pinus* spp.), sometimes mixed with codominant hardwood trees, over a variety of different types of shrub and herb layers.

FFMH – Mixed Hardwood Floodplain Forest

The Mixed Hardwood Floodplain Forest (FFMH) map class represents the following five associations in the USNVC:

- *Acer* rubrum var. *trilobum* - *Fraxinus pennsylvanica* / *Carex crinita* - *Peltandra virginica* Floodplain Forest (CEGL004420),
- *Platanus occidentalis* - *Liriodendron tulipifera* - (*Betula alleghaniensis*) / *Alnus serrulata* - *Leucothoe fontanesiana* Floodplain Forest (CEGL004691),
- *Tsuga canadensis* - *Liriodendron tulipifera* - *Platanus occidentalis* / *Rhododendron maximum* - *Xanthorhiza simplicissima* Wet Forest (CEGL007143),
- *Platanus occidentalis* - *Fraxinus pennsylvanica* - *Quercus imbricaria* Floodplain Forest (CEGL007339), and
- *Liquidambar styraciflua* - *Liriodendron tulipifera* - (*Platanus occidentalis*) / *Halesia tetraptera* / *Amphicarpaea bracteata* Floodplain Forest (CEGL007880).

This map class represents mixed-species deciduous forest that are always associated with riparian zones on flat valley bottoms and generally is limited to a very narrow band along the waterway. Present only at the lower elevations, FFMH was confined to riparian zones below 1,000 m elevation along large streams and small rivers. Additionally, this map class often exists on riparian islands in these waterways. In the project imagery, FFMH tends to appear as a mixed hardwood forest in long, narrow bands on the flats along riparian zones. In several instances, the band of FFMH while present, was too narrow and small to warrant mapping. The FFMH map class is uncommon within the Park covering 276.7 ha (0.1% of GRSM).

The AA results indicate that FFMH was mapped with a users' accuracy of 93% and a producers' accuracy of 97%. The AA discloses two instances where FFMH was mapped too aggressively and only one instance where FFMH was mapped too conservatively. In all instances, the confusion was caused by the misestimation of the degree of riparian influence on the system.

Four examples of the FFMH map class showing CEGL004691 with large, mature American sycamore (*Platanus occidentalis*) (upper left), CEGL007143 with many tall tuliptree (*Liriodendron tulipifera*) and American sycamore (upper right), CEGL007339 with a diverse mix of hardwood trees including shingle oak (*Quercus imbricaria*) (lower left), and CEGL007880 with a sweetgum (*Liquidambar styraciflua*) dominated canopy (lower right). All examples are within the riparian zone.

FUSP – Upland Sweetgum - Red Maple Pond

The Upland Sweetgum - Red Maple Pond (FUSP) map class represents the *Liquidambar styraciflua* - *Acer rubrum* / *Carex* spp. - *Sphagnum* spp. Seep Forest Association (CEGL007388) in the USNVC. The forest association that makes up this map class occurs in one location in the Park. The FUSP map class is extremely rare within the Park covering only 2.3 ha (0.001% of GRSM).

This sweetgum (*Liquidambar styraciflua*) dominated swamp map class is found in one basin at the west end of Cades Cove. In the project imagery, FUSP presents as a sweetgum-dominated swamp-basin forest that is tall statured with tan-to-gold-crowned sweetgum trees.

The FUSP map class was mapped very consistently. The AA process discovered no new instances of the FUSP map class, and no instances of FUSP were confused with a different map class.

An example of the FUSP map class showing the large, mature sweetgum (*Liquidambar styraciflua*) dominated canopy over a basin showing the effects of repeated inundation.

FXSH – Southern Appalachian Ruderal Acidic Mixed Hardwood Forest

The Southern Appalachian Ruderal Acidic Mixed Hardwood Forest (FXSH) map class represents the *Acer rubrum* - *Betula lenta* - *Magnolia fraseri* / (*Rhododendron maximum*, *Kalmia latifolia*) Ruderal Forest Association (CEGL008558) in the USNVC. The forest association that makes up this map class primarily represents native ruderal hardwood forest found at mid-elevations resulting from disturbance events in the last 50–100 years. The FXSH map class is common within the Park covering 1,286.3 ha (0.6% of GRSM).

The FXSH map class presents a variable and confusing signature in the project imagery that is related to the conditions present when the site was colonized by trees, to what tree species are dominant, and to the density of the underlying evergreen shrub layer. The uniting factor is that these are younger forest stands that are dominated by a variety of non-northern hardwood tree species, that lack tuliptree (*Liriodendron tulipifera*), and that generally are not found in the topographic cove position on the landscape. In the project imagery, the hardwoods in the FXSH map class generally present as smaller, fuzzy crowns of yellow and orange (and occasionally leafless) with the reddish "glow" of underlying evergreen shrubs.

The AA results indicate that FXSH was mapped with a users' accuracy of 63% (90% confidence interval of 47–79%) and a producers' accuracy of 76% (90% confidence interval of 60–92%). The AA discloses many instances where FXSH was mapped either too aggressively (to two map classes) or too conservatively (from five map classes). The over mapping of FCES as FXSH was somewhat chronic with 10 instances and likely was the result of drought-stressed oak heath appearing as leaf-off hardwood trees. The under mapping of FXSH across the five map classes indicated no pattern and likely was the result of the misidentification of hardwood species and their relative canopy density.

The 90% confidence interval for the users' accuracy remains below the standard. Decisions with GRSM staff resulted in accepting a slightly lower producers' accuracy for the FXSH map class instead of merging more map classes together to boost accuracy results. Information on this decision is in "Appendix D: Accuracy Assessment Reconciliation."

An example of the FXSH map class showing the younger non-northern hardwood canopy over evergreen shrub.

FXTW – Ruderal Tuliptree - Walnut Forest

The Ruderal Tuliptree - Walnut Forest (FXTW) map class represents the following four associations in the USNVC:

- *Liriodendron tulipifera - Acer negundo* Ruderal Forest (CEGL007184),
- *Liriodendron tulipifera* / (*Cercis canadensis*) / (*Lindera benzoin*) Ruderal Forest (CEGL007220),
- *Liriodendron tulipifera - Quercus* spp. Ruderal Forest (CEGL007221), and
- *Juglans nigra* / *Verbesina alternifolia* Ruderal Forest (CEGL007879).

The ruderal forest associations that make up this map class occur widely across the lower elevations of the Park and are especially common in the valleys where historical settlement and agriculture occurred. The FXTW map class is very common within the Park covering 9,788.4 ha (4.6% of GRSM).

The FXTW map class presents a variable signature in the project imagery that is related to the conditions present when the site was colonized by tuliptree (*Liriodendron tulipifera*) or black walnut (*Juglans nigra*). This variation in signature results from tree stands that vary from even-aged 200-year old groves, or older, of tuliptree to young, scraggily mixed-species stands still dominated by tuliptree or black walnut. The uniting factor is that these are ruderal forest stands dominated by tuliptree or black walnut. The signature in the project imagery and the landscape position proved difficult to concisely constrain; but, generally, tuliptree presents as a pink (sometimes white, orange, or red) conical (except in very large individuals where the crown becomes broken) tree. For FXTW, this signature often meant an extensive area of pink conical trees all the same height and size. Additionally, FXTW was primarily found at lower elevations; most sites at less than 1,100 m elevation.

The AA results indicate that FXTW was mapped with a users' accuracy of 77% (90% confidence interval of 62–91%) and a producers' accuracy of 59% (90% confidence interval of 45–73%). The AA discloses many instances where FXSH was mapped either too aggressively (to three map classes) or too conservatively (from nine map classes). Of these errors, the FAHC, FAEC, and FXAH map classes caused concern with confusion in users' accuracy and producers' accuracy. The FXAH map class caused the most concern because of chronic confusion with the consistent misestimation of tuliptree and black walnut cover in the canopy.

The 90% confidence interval for the producers' accuracy remains below the standard. Decisions with GRSM staff resulted in accepting a lower producers' accuracy for the FXTW map class instead of merging more map classes together to boost accuracy results. Information on this decision is in "Appendix D: Accuracy Assessment Reconciliation."

Four examples of the FXTW map class showing CEGL007184 (upper left), CEGL007220 (upper right), CEGL007221 (lower left), and CEGL007879 (lower right). All examples show a ruderal forest dominated by some mix of tuliptree (*Liriodendron tulipifera*) or black walnut (*Juglans nigra*) over different types of ruderal shrub and herb layers.

FXAH – Appalachian Ruderal Hardwood Forest

The Appalachian Ruderal Hardwood Forest (FXAH) map class represents the *Liriodendron tulipifera - Acer rubrum - Robinia pseudoacacia* Ruderal Forest Association (CEGL007219) in the USNVC. The forest association that makes up this map class primarily represents ruderal hardwood forest not dominated by a single species in the Park. The FXAH map class is common within the Park covering 4,159.5 ha (2.0% of GRSM).

The FXAH map class presents a variable signature in the project imagery that is related to the conditions present when the site was colonized by trees, but in all instances, this map class is a younger, very disturbed forest. The uniting factor is that these are ruderal forest stands dominated by a variety of hardwood tree species and not dominated (less than 50% canopy cover) by tuliptree (*Liriodendron tulipifera*). Generally, the hardwoods in this map class present as small, short fuzzy crowns of white, yellow, orange, and pink (and occasionally leafless) intermixed with tuliptree with a pink (sometimes white, orange, or red) conical crown. Additionally, this map class can have associated canopy cover (less than 25%, each) of ruderal oak species (*Quercus* spp.) or ruderal pine species (*Pinus* spp.), which provides a further level of confusion and complexity. Potentially located on any landscape position below 1,400 m elevation, this map class occurred broadly across the lower elevations of the Park.

The AA results indicate that FXAH was mapped with a users' accuracy of 60% (90% confidence interval of 44–76%) and a producers' accuracy of 55% (90% confidence interval of 39–70%). The AA discloses many instances where FXAH was mapped either too aggressively (to five map classes) or too conservatively (from seven map classes). Mapping errors for the FXAH map class spanned the spectrum compared to other ruderal forest map classes. More than one-half of the mapping errors were from the misestimation of tree species canopy, followed by the underestimation of oak cover and the misinterpretation of the degree of disturbance present in the forest.

The 90% confidence interval for the users' and producers' accuracies remain below the standard. Decisions with GRSM staff resulted in accepting lower accuracies for the FXAH map class instead of merging more map classes together to boost accuracy results. Information on this decision is in "Appendix D: Accuracy Assessment Reconciliation."

Two examples of the FXAH map class showing the mixed ruderal hardwood forest canopy over deciduous shrub and sparse herb of CEGL007219 (left) versus the mixed ruderal hardwood forest canopy over dense evergreen shrub of CEGL008558 (right).

FXBL – Ruderal Black Locust Forest

The Ruderal Black Locust Forest (FXBL) map class represents the *Robinia pseudoacacia* Ruderal Forest Association (CEGL007279) in the USNVC. The forest association that makes up this map class was only found in the area of Purchase Knob in the Park, but has the potential to occur throughout the Park. The FXBL map class is exceptionally rare in the Park covering 1.3 ha (0.0006% of GRSM).

Dominated by a monotypic stand of black locust (*Robinia pseudoacacia*), the FXBL map class occurs in old fields where the tree readily spreads through root sprouting. Root sprouting presents the mappers with a unique imagery signature that appears as a mound of identical trees with the tallest trees in the middle and progressively shorter trees as the edge of the stand is approached. In the project imagery, FXBL has a unique light and fuzzy signature caused by the small, diffuse leaves on the black locust tree that senesce early in the fall. Black locust is very common in older disturbed forests in the Park. However, only two monocultures were large enough to map.

The FXBL map class was mapped very consistently. The AA process discovered no new instances of the FXBL map class, and no instances of FXBL were confused with a different map class.

An example of the FXBL map class showing the characteristically diffuse canopy of black locust (*Robinia pseudoacacia*) over a ruderal shrub and herb layer.

FXSG – Ruderal Sweetgum Forest

The Ruderal Sweetgum Forest (FXSG) map class represents the *Liquidambar styraciflua* Ruderal Forest Association (CEGL007216) in the USNVC. The forest association that makes up this map class was only found on the Tennessee side of the Park but has the potential to occur throughout lowest elevations of the Park. The FXSG map class is rare in the Park covering 29.6 ha (0.01% of GRSM).

Dominated by sweetgum (*Liquidambar styraciflua*), the FXSG map class occurs in old fields where the tree readily spreads through root sprouting. In the project imagery, FXSG has a unique orange-to-gold color with the sweetgum trees to provide a distinctive signature, especially when growing in a near monoculture.

The AA results indicate that FXSG was mapped with a users' accuracy of 78% (90% confidence interval of 59–97%) and a producers' accuracy of 88%. The AA discloses two instances where FXSG was mapped too aggressively and two instances where FXSG was mapped too conservatively. These errors primarily result from a misestimation of sweetgum canopy density with co-occurring ruderal forest map classes and an overestimation of sweetgum canopy cover in a shrub map class.

An example of the FXSG map class showing the characteristically monotypic stand of sweetgum (*Liquidambar styraciflua*) over a ruderal shrub and herb layer.

FXWP – Ruderal Eastern White Pine Forest

The Ruderal Eastern White Pine Forest (FXWP) map class represents the *Pinus strobus* Ruderal Forest Association (CEGL007944) in the USNVC. The forest association that makes up this map class occurs throughout the lower elevations of the Park. The FXWP map class is common within the Park covering 2,179.3 ha (1.0% of GRSM).

The FXWP map class ranges from codominance to complete dominance of eastern white pine (*Pinus strobus*) of a ruderal nature. Generally, this map class presents as even-aged stands of younger-to-mature eastern white pine covering a subcanopy of hardwoods over a generally open and disturbed shrub and herb layer. A consistent difference between the FXWP and FAWP map classes is that FAWP presents in the project imagery as a mature uneven-growth forest with large-sized eastern white pine having a distinct pattern of branches perpendicular to the trunk.

The AA results indicate that FXWP was mapped with a users' accuracy of 60% (90% confidence interval of 44–76%) and a producers' accuracy of 82%. The AA discloses many instances where FXWP was mapped too aggressively (to six map classes) and one instance where FXWP was mapped too conservatively. The primary source of confusion was with the FAEC map class, which can have eastern white pine codominant to dominant in cove setting, but not disturbed and over great laurel (*Rhododendron maximum*). Because of the inability to clearly gauge the amount of great laurel cover under a thick eastern white pine canopy, mappers had difficulty differentiating these two map classes. Other issues arise from the overestimation for either the amount of eastern white pine in the canopy or the amount of disturbance at the site.

The 90% confidence interval for the users' accuracy remains below the standard. Decisions with GRSM staff resulted in accepting a lower producers' accuracy for the FXWP map class instead of merging more map classes together to boost accuracy results. Information on this decision is in "Appendix D: Accuracy Assessment Reconciliation."

An example of the FXWP map class showing a young, broken canopy dominated by eastern white pine (*Pinus strobus*) over a depauperate shrub and herb layer, indicating a history of significant disturbance.

FXNS – Ruderal Norway Spruce Forest

The Ruderal Norway Spruce Forest (FXNS) map class represents the *Picea abies* Forest Plantation Cultural Subtype (CST007167) in the USNVC. The forests that represent this map class were formerly planted to Norway spruce, potentially as part of Civilian Conservation Corps efforts in the 1930s. These forests are unmanaged and are only found in a very limited portion of the Park along the Grassy Branch Trail. The FXNS map class is extremely rare within the Park covering 5.0 ha (0.002% of GRSM).

This map class is defined by areas of conifer dominated by Norway spruce (*Picea abies*), a tree species not native to the Park. The few areas of this map class that were visited showed little regeneration of Norway spruce; therefore, this map class is unlikely to sustain on the landscape.

The FXNS map class was mapped very consistently. The AA process discovered no new instances of the FXNS map class, and no instances of FXNS were confused with a different map class.

An example of the FXNS map class showing Norway spruce (*Picea abies*) along the Grassy Branch Trail in North Carolina.

SBMH – Southern Appalachian Mixed Heath Bald

The Southern Appalachian Mixed Heath Bald (SBMH) map class represents the following three associations in the USNVC:

- *Kalmia latifolia - Rhododendron catawbiense* - (*Gaylussacia baccata*, *Pieris floribunda*, *Vaccinium corymbosum*) Shrubland (CEGL003814),
- *Leiophyllum buxifolium* Dwarf-shrubland (CEGL003951), and
- *Rhododendron carolinianum - Rhododendron catawbiense - Leiophyllum buxifolium* Shrubland (CEGL007876).

The shrubland associations that make up this map class occur across a wide range of elevations in the Park and are tied to ridge tops and very thin, rocky soils. The SBMH map class is uncommon within the Park covering 691.5 ha (0.3% of GRSM).

Initially, these three associations were mapped as two different map class—CEGL003814 was represented by a low-elevation shrub bald map class and CEGL003951 and CEGL007876 were represented by a high-elevation shrub bald map class. However, the AA quickly determined that CEGL003814 occurred consistently across all elevation ranges in the Park; therefore, the decision was made to collapse these three associations into a single map class. Information on this decision is in "Appendix D: Accuracy Assessment Reconciliation."

The SBMH map class is defined by evergreen shrubs on ridge crests and steep slopes. The presence of evergreen shrubs generally excludes the map class from the other shrub classes. On occasion, trees were mixed in with the shrubs, but because of the vibrant-red signature of the evergreen shrubs in the project imagery, the SBMH map class was easy to map.

The AA results indicate that SBMH was mapped well a users' accuracy of 91% and a producers' accuracy of 98%. The AA discloses several instances where SBMH was mapped either too aggressively (to three map classes) or too conservatively (from one map class). These errors were caused by either a misestimation of tree canopy cover (over and under) or an overestimation of shrub cover.

Two examples of the SBMH map class showing the dense evergreen shrub stems of a CEGL003814 from below (left) and the solid evergreen canopy of a CEGL007876 from above with a few short trees mixed in (right).

SDAB – Southern Appalachian Hybrid Deciduous Azalea Bald

The Southern Appalachian Hybrid Deciduous Azalea Bald (SDAB) map class represents the *Rhododendron* (*calendulaceum*, *cumberlandense*) Appalachian Bald Shrubland Park (CEPS009759), a park-special type. The shrub type that makes up this map class was only found on Gregory Bald within the Park but has the potential to occur in isolated pockets at high elevation throughout the Park. The SDAB map class is extremely rare in the Park covering only 1.3 ha (0.0006% of GRSM).

The SDAB map class is defined by deciduous rhododendron (commonly called azalea) species (*Rhododendron* spp.) dominating at high elevation. These factors combined well with the distinct raised brown signature of these deciduous rhododendrons in the project imagery.

The SDAB map class was mapped very consistently. The AA process discovered no new instances of the SDAB map class, and no instances of SDAB were confused with a different map class.

An example of the SDAB map class showing deciduous rhododendron (commonly called azalea) species (*Rhododendron* spp.) in bloom with the different colors representing different species or potential hybrids.

SHBT – High-Elevation Blackberry Thicket

The High-Elevation Blackberry Thicket (SHBT) map class represents the following four associations in the USNVC:

- *Rubus allegheniensis* - *Rubus canadensis* / *Carex pensylvanica* Shrubland (CEGL003892),
- *Rubus canadensis* - (*Rubus idaeus* ssp. *strigosus*) / *Athyrium filix-femina* - *Solidago glomerata* Shrubland (CEGL003893),
- *Crataegus punctata* - *Crataegus flabellata* Ruderal Forest (CEGL004184), and
- (*Prunus pensylvanica*, *Sorbus americana*) - *Rubus* spp. Shrubland (CEGL007293).

The shrubland and forest associations that make up this map class are scattered across the higher elevations of the Park and are especially common in the spruce-fir zone. The SHBT map class is rare within the Park covering 52.4 ha (0.02% of GRSM).

Initially, mappers saw this map class as three separate map classes and one unmapped association—CEGL003892 representing a natural blackberry species (*Rubus* spp.) bald, CEGL003893 representing a ruderal blackberry thicket, CEGL007293 representing a mixed short tree-blackberry thicket, and CEGL004184 representing an unmapped ruderal woodland. The AA indicated that these map classes and corresponding associations were systematically confused; therefore, the decision was made to collapse the group into a single map class. Information on this decision is in "Appendix D: Accuracy Assessment Reconciliation."

The SHBT map class is defined by shrub dominance, specifically blackberry, at higher than 1,400 m elevation and not in association with natural balds. Occasionally, short-statured trees will codominate over the blackberry. Most commonly, the SHBT map class was present where extensive soil modification had occurred, which is believed to result from grazing, landslides, or severe fire. Additionally, patches of SHBT were often associated with forest opening. In the project imagery, SHBT generally presents as a flat, dark-tan to brownish-red area.

The AA results indicate that SHBT was mapped well with a users' accuracy of 81% and a producers' accuracy of 100%. The AA discloses two instances where SHBT was mapped too aggressively. The errors were caused by either underestimation of tree canopy cover or overestimation of shrub cover.

Four examples of the SHBT map class showing CEGL003892 (in late fall) showing dense blackberry species (*Rubus* spp.) canes (upper left), CEGL003893 showing dense blackberry canes (upper right), CEGL004184 showing a short tree canopy (lower left), and CEGL007293 showing dense blackberry canes with a sparse short tree canopy (lower right).

HGBF – Grassy Bald (Southern Grass Type)

The Grassy Bald (Southern Grass Type) (HGBF) map class represents the *Danthonia compressa* - (*Sibbaldiopsis tridentata*) Grassland Association (CEGL004242) in the USNVC. The herbaceous association that makes up this map class only occurs above 1,400 m elevation in the Park. The HGBF map class is extremely rare in the Park covering only 3.7 ha (0.002% of GRSM).

The HGBF map class is highly constrained by elevation and land-use history. This map class naturally occurs only at the highest elevations. Generally, the HGBF map class favored southern exposures at the top of the highest peaks within the Park and appeared as tan to light-pink, very short-statured herbaceous vegetation in the project imagery. Small patches of shrubs were common within this map class, especially in areas lacking recent management.

The HGBF map class was mapped very consistently. The AA process discovered no new instances of the HGBF map class, and no instances of HGBF were confused with a different map class.

An example of the HGBF map class showing the short grass and forb cover with sparse tree canopy characteristic of CEGL004242.

HSGF – Graminoid and Forb Rocky Summit

The Graminoid and Forb Rocky Summit (HSGF) map class represents two associations in the USNVC—the *Saxifraga michauxii - Carex misera - Oclemena acuminata - Solidago glomerata* Grassland (CEGL004277) and the *Saxifraga michauxii - Carex misera - Danthonia spicata - Krigia montana* Grassland (CEGL004279). This herbaceous map class is only known from a single mappable location in the Park, about 1 mile north of the Ramsey Cascade Trail, and was identified through aerial imagery interpretation. The HSGF map class is exceptionally rare in the Park covering only 0.5 ha (0.0002% of GRSM).

The HSGF map class is highly constrained by elevation and bed rock type. Occurring only on bedrock not of the Anakeesta Formation, the HGBF map class is only found in areas of exposed stone and generally on very steep, exfoliating slopes. Many areas below the 0.25-ha MMU occur in the Park, but only one area met the MMU size. In the project imagery, HSGF appeared as a sparsely vegetated tan to light-pink, very short-statured herbaceous vegetation.

Because of the remoteness of the HSGF map class, HSGF proved inaccessible for AA. Therefore, the HSGF map class was not tested for accuracy.

A visual example is not available for the HSGF map class.

HBAS – Southern Appalachian High-Elevation Rocky Summit (Anakeesta Type)

The Southern Appalachian High-Elevation Rocky Summit (Anakeesta Type) (HBAS) map class represents the *Saxifraga michauxii* - *Carex misera* - *Calamagrostis cainii* Grassland Association (CEGL004278) in the USNVC. The herbaceous association that makes up this map class was only found above 1,400 m elevation in the Park. The HBAS map class is extremely rare within the Park covering only 20.6 ha (0.01% of GRSM).

The HBAS map class is highly constrained by elevation and bedrock and only occurs over bedrock of the Anakeesta Formation. Generally, the HGBF map class exists on very steep and exfoliating slopes around the top of the highest peaks within the Park. In the project imagery, HBAS presents as tan to light-pink, very short-statured herbaceous vegetation. Small patches of shrubs were common within this map class.

The AA results indicate that HBAS was mapped well with a users' accuracy of 100% and a producers' accuracy of 83%. The AA discloses only one instance where HBAS was mapped too conservatively from the SBMH map classes. This error is from overestimation of total shrub cover.

An example of the HBAS map class showing the short grass and forb cover with sparse tree canopy on a very steep exfoliating slope characteristic of CEGL004278.

SMRT – Montane Rhododendron Thicket

The Montane Rhododendron Thicket (SMRT) map class represents two associations in the USNVC—the *Rhododendron maximum* Montane Ruderal Thicket (CEGL003819) and the *Rhododendron maximum* / *Sphagnum* spp. Seepage Shrubland (CEGL003849). This evergreen shrub map class occurs below 1,200 m elevation in cove bottoms and in areas where catastrophic disturbance has removed the tree canopy of acidic coves. The SMRT map class is extremely rare within the Park covering only 17.9 ha (0.009% of GRSM).

Initially, these two associations were mapped apart based on the different hydrologic conditions, but the AA indicated consistent confusion between the two associations. Therefore, the decision was made to collapse the two associations into a single map class. Information on this decision is in "Appendix D: Accuracy Assessment Reconciliation."

The SMRT map class is defined by great laurel (*Rhododendron maximum*), which does not occur at high elevation (above 1,220 m). Occasionally, deciduous trees were scattered in with the shrubs, but because of the vibrant-red signature of the great laurel in the project imagery, the SMRT map class was easy to determine. A final variation on this map class was caused by a catastrophic tornado that hit part of the Park on April 11, 2011. This event destroyed tree cover in several acidic cove forests. The underlying great laurel recovered before the tree canopy, resulting in large linear areas of this map class in disturbed cove bottoms.

The AA results indicate that SMRT was mapped with a users' accuracy of 50% (90% confidence interval of 8–92%) and a producers' accuracy of 100%. The AA discloses two instances where SMRT was mapped too aggressively to the FXAH and FXSG map classes. These errors were caused by underestimating remnant tree canopy cover in areas altered by the tornado.

An example of the SMRT map class showing the solid wall of great laurel (*Rhododendron maximum*) and the twisted trunks of downed trees.

SGHO – Montane Grape Opening

The Montane Grape Opening (SGHO) map class represents the *Vitis aestivalis* Vine-Scrub Association (CEGL003890) in the USNVC. This vining woody vegetation map class occurs in disturbed, rich coves below 1,220 m elevation and is markedly more common on the Tennessee side of the Park. The SGHO map class is uncommon within the Park covering 360.8 ha (0.2% of GRSM).

The summer grape (*Vitis aestivalis*) is a native vining shrub capable of climbing all the way to the canopy of the tallest trees in coves. During successive seasons, the vines eventually smother and pull down supporting trees. Always occurring in the lower elevations (below 1,220 m) of the Park in rich coves and tending towards the north aspect, the SGHO resides in a landscape resulting in a truly unique signature in the project imagery having a very consistent light tan-to-gray color with a mogul or lumpy texture.

The AA results indicate that SGHO was mapped well with a users' accuracy of 96% and a producers' accuracy of 100%. The AA discloses only one instance where SGHO was mapped too aggressively to the FOHM map class when total standing tree cover was underestimated.

Two examples of the SGHO map class showing CEGL003890 from below with many intertwined vines (left) and from above with a smothering carpet of vines covering every available surface (right).

SFCB – Floodplain Canebrake

The Floodplain Canebrake (SFCB) map class represents the *Arundinaria gigantea* ssp. *gigantea* Wet Canebrake Association (CEGL003836) in the USNVC. This shrub association consists of monotypic stands of giant cane (*Arundinaria gigantea* ssp. *gigantea*) and only is found in the floodplains of Cades Cove. The SFCB map class is extremely rare in the Park covering only 1.8 ha (0.0009% of GRSM).

The SFCB map class is defined by monotypic stands of giant cane (a native species of bamboo, a giant grass) dominating moist, rich soils in the floodplain of low elevation streams and rivers. These factors combined well with the distinct very tall herbaceous, bright-red signature stands in the project imagery.

The SFCB map class was mapped very consistently. The AA process discovered no new instances of the SFCB map class, and no instances of SFCB were confused with a different map class.

An example of the SFCB map class showing CEGL003836 with an extensive stand of giant cane (*Arundinaria gigantea* ssp. *gigantea*) in Cades Cove.

HLAG – Low-Elevation Acidic Glade (Grass Type)

The Low-Elevation Acidic Glade (Grass Type) (HLAG) map class represents the (*Quercus montana*) / *Vaccinium pallidum* / *Schizachyrium scoparium* - *Danthonia spicata* / *Cladonia* spp. Scrub Grassland Association (CEGL004990) in the USNVC. The herbaceous association that makes up this map class was only found at one site along the Appalachian National Scenic Trail. The HLAG map class is the rarest map class in the Park covering only 0.3 ha (0.0002% of GRSM).

The HLAG map class was only found at one site in the Park on a steep, low-elevation slope of exfoliating bedrock. In the project imagery, HLAG presents as tan-to-white, very short-statured herbaceous vegetation and bare rock. Small patches of shrubs were present within this map class along with the Appalachian National Scenic Trail, which bisects the site.

The HLAG map class was not tested during the AA phase. Because it was a single site supported by field reconnaissance notes and vegetation plot data, investigating this single, remote site was determined unnecessary.

An example of the HLAG map class showing the short grass and forb cover on very steep rock characteristic of CEGL004990.

SSAS – Southeastern Alder Swamp

The Southeastern Alder Swamp (SSAS) map class represents the *Alnus serrulata* Southeastern Seasonally Flooded Shrubland Association (CEGL008474) in the USNVC. This wetland shrub association is generally dominated hazel alder (*Alnus serrulata*) and other wetland herbs and shrubs. The SSAS map class is extremely rare in the Park covering only 2.4 ha (0.001% of GRSM).

The SSAS map class is a wetland shrub map class generally dominated by hazel alder. The map class generally occurs on flat floodplains and basins at the lowest elevations of the Park on enriched soils. In the project imagery, the hazel alder in SSAS presents as tall, mounded, bright-red shrubs with obvious wetland influence.

The SSAS map class was mapped very consistently. The AA process discovered no new instances of the SSAS map class, and no instances of SSAS were confused with a different map class.

An example of the SSAS map class showing CEGL008474 with an extensive stand of hazel alder (*Alnus serrulata*) in the background and wetland herbaceous vegetation in the foreground.

HXCR – Ruderal Common Rush Marsh

The Ruderal Common Rush Marsh (HXCR) map class represents two associations in the USNVC—the *Juncus effusus* Marsh (CEGL004112) and the *Juncus effusus* - *Chelone glabra* - *Scirpus* spp. Southern Blue Ridge Beaver Pond Ruderal Marsh (CEGL008433). The ruderal herbaceous marsh associations that define this map class primarily represent naturally disturbed wetlands at low elevations in the Park. The HXCR map class is extremely rare within the Park covering 8.2 ha (0.004% of GRSM).

The HXCR map class is defined by open, disturbed wetlands where common rush (*Juncus effusus*) dominates (greater than 50% cover). Because small areas can easily be dominated by common rush, less than MMU patches of this map class are likely in any disturbed wetland setting, especially in areas with ongoing American beaver (*Castor canadensis*) activity. In the project imagery, HXCR generally presents as a flat, light- to bright-pink herbaceous field on regularly inundated areas and as the distinctive mixed herbaceous-shrub vegetation behind a beaver pond.

The HXCR map class was mapped very consistently. The AA process discovered no new instances of the HXCR map class, and no instances of HXCR were confused with a different map class.

Two examples of the HXCR map class showing a location with CEGL004112 and an extensive area dominated by common rush (*Juncus effusus*) (left) and a beaver pond in Cades Cove, Tennessee, with the greater diversity of CEGL008433, but still dominated by common rush (right).

HSCP – Smartweed - Cutgrass Beaver Pond

The Smartweed - Cutgrass Beaver Pond (HSCP) map class represents the *Polygonum* (*hydropiperoides*, *punctatum*) - *Leersia* spp. Shoreline Wet Meadow Association (CEGL004290) in the USNVC. The wet herbaceous association that makes up this map class only occurs as a mappable unit in the Park in one location in Cades Cove. The HSCP map class is exceptionally rare within the Park covering 0.4 ha (0.0002% of GRSM).

In GRSM, the HSCP map class is a depressional wetland that often occurs in sinkholes over calcareous (limestone) bedrock. An interesting aspect of sinkhole wetlands is the rapidness with which water levels can fluctuate. In this wetland, project imagery showed a completely dry, fully vegetated wetland. In the project imagery, HSCP presents as a depression covered in bright-red herbaceous vegetation with sparse tall shrubs or short trees spread about the depression.

The HSCP map class was not tested during the AA phase. Because the map class was represented by one site that was supported by Park management notes, investigating the single, remote site was determined to be unnecessary.

An example of the HSCP map class showing CEGL004490 during a dry period with dense, tall herbaceous vegetation, several short trees, and no water (image example courtesy of Great Smoky Mountains National Park).

SXBG – Ruderal Blackberry - Greenbrier Shrub Thicket

The Ruderal Blackberry - Greenbrier Shrub Thicket (SXBG) map class represents two associations in the USNVC—the *Rubus* (*argutus*, *trivialis*) - *Smilax* (*glauca*, *rotundifolia*) Ruderal Shrubland (CEGL004732) and the *Glyceria striata - Carex gynandra - Chelone glabra - Symphyotrichum puniceum / Sphagnum* spp. Herbaceous Seep (CEGL008438). The ruderal shrub associations that define this map class primarily represent highly disturbed lands regenerating to shrub and short trees. The SXBG map class is rare within the Park covering 44.7 ha (0.02% of GRSM).

The SXBG map class was originally defined by only CEGL004732, but during the AA process, CEGL008438 was found in the map class in more wet, disturbed areas. The AA determined that the CEGL008438 association was not mapped in any other map class or found in any other map class. Therefore, the decision was made to add CEGL008438 to SXBG. Information on this decision is in "Appendix D: Accuracy Assessment Reconciliation."

The SXBG map class is a highly variable mix of native and non-native ruderal herb, shrub, and tree species with at least 25% shrub cover and less than 25% tree cover; however, only trees taller than 5 m were counted as trees. Deciduous and evergreen shrubs were allowed in the map class. This map class also can apply to managed landscape modifications that interrupt natural succession on a regular basis; however, rights-of-way areas, such as power-line corridors and road sides, are mapped with the CDVL map class.

In the project imagery, SXBG presents a highly variable signature that is related to the conditions present when the site was recolonized by shrubs, but in all instances, this map class is in very disturbed areas. The uniting factor is that these ruderal shrub stands are dominated by a variety of shrub species and are not dominated (less than 50% cover) by native evergreen heath shrubs such as great laurel (*Rhododendron maximum*) or mountain laurel (*Kalmia latifolia*). Potentially located on any low-elevation landscape position, this map class was restricted to areas with ongoing active management.

The AA results indicate that SXBG was mapped with a users' accuracy of 73% (90% confidence interval of 57–89%) and a producers' accuracy of 100%. The AA discloses five instances where SXBG was mapped too aggressively. The errors mainly divide into two groups. The first group is from misestimation of ruderal shrub cover in co-occurring forest (underestimation) and ruderal herbaceous (overestimation) map classes. The second group is from underestimation of deciduous vine cover in the co-occurring SXKV map class.

Two examples of the SXBG map class showing a location repeatedly returned to an herb or shrub condition by active management (left) and a location maturing from a shrubland into a young ruderal forest (right).

SXKV – Ruderal Kudzu Vineland

The Ruderal Kudzu Vineland (SXKV) map class represents the *Pueraria montana* var. *lobata* Ruderal Vine-Shrubland Association (CEGL003882) in the USNVC. The vining woody vegetation of this map class occur along the edges of the Park and is actively managed against within the Park. The SXKV map class is exceptionally rare within the Park covering 1.8 ha (0.0009% of GRSM).

The kudzu (*Pueraria montana* var. *lobata*) vine is a highly-invasive non-native woody vine that is widely dispersed across the landscape and poses a significant management challenge. In the very few instances where a mappable area was found, a mat-forming monoculture smothered all other vegetation in the area. This provided the mappers with a very consistent, vibrant red signature in the project imagery that looked like a sheet was draped over the existing landscape of hills, trees, and shrubs. More examples of this map class exist outside the Park's boundary.

The AA results indicate that SXKV was mapped with a users' accuracy of 100% and a producers' accuracy of 60% (90% confidence interval of 14–106%). (Because of the rarity of this map class within the Park, the number of potential AA sites was restricted; thus, resulting in a wide range in confidence intervals.) The AA indicated only two instances where SXKV was mapped too conservatively. In both instances, the cover of Kudzu vine was underestimated in the ruderal shrub (SXBG) and ruderal herb (HXMC) map classes.

An example of the SXKV map class showing a kudzu (*Pueraria montana* var. *lobata*) smothered landscape.

HXFM – Grazed Montane Grassland / Fire Meadow

The Grazed Montane Grassland / Fire Meadow (HXFM) map class represents the *Phleum pratense* - *Bromus pubescens* - *Helenium autumnale* Ruderal Meadow Association (CEGL004018) in the USNVC. This herbaceous association only occurs in actively managed areas of the Park on occasionally managed herbaceous fields above 1,220 m elevation. The HXFM map class is exceptionally rare within the Park covering only 16.1 ha (0.008% of GRSM).

This mixed-species herbaceous map class requires occasional management to prevent succession into woody vegetation and, generally, is closely associated with landscapes managed for historical and cultural reasons. Additionally, the species composition between HXFM and HXCM is otherwise indistinguishable in the project imagery, but is elevation dependent; therefore, an elevation cutoff of 1,220 m was used to split the two map classes. In the project imagery, HXFM presents a bright-pink or red signature of managed herbaceous fields associated with human-dominated landscapes; however, fields without recent management could appear a much lighter pink-to-tan if the fields had sufficient dead vegetation and often had notable, if less than MMU, patches of blackberry species (*Rubus* spp.).

The AA results indicate that HXFM was mapped with a users' accuracy of 90% and a producers' accuracy of 69% (90% confidence interval of 44–94%). The AA discloses two instances where HXFM was mapped either too aggressively (to the HXCM map class where the low-elevation type occurred above the expected elevation) or too conservatively (from the SHBT map class where blackberry cover was underestimated).

An example of the HXFM map class showing a graminoid-dominated areas at Purchase Knob in North Carolina.

HXCM – Cultivated Grassland

The Cultivated Grassland (HXCM) map class represents the *Schedonorus* (*arundinaceum*, *pratense*) Ruderal Grassland Association (CEGL004048) in the USNVC. This herbaceous association only occurs in actively managed areas of the Park on herbaceous fields and usually below 1,220 m elevation. The HXCM map class is uncommon within the Park covering 854.9 ha (0.4% of GRSM).

This mixed-species herbaceous map class requires continual management to prevent succession into woody vegetation and, generally, is closely associated with landscapes managed for historical and cultural reasons. Additionally, the species composition between HXCM and HXFM is otherwise indistinguishable in the project imagery, but is elevation dependent; therefore, an elevation cutoff of 1,220 m was used to split the two map classes. In the project imagery, HXCM presents a bright-pink or red signature of managed herbaceous fields associated with human-dominated landscapes; however, fields without recent management could appear a much lighter pink-to-tan if the fields had sufficient dead vegetation.

The AA results indicate that HXCM was mapped well with a users' accuracy of 97% and a producers' accuracy of 90%. The AA discloses one instance where HXCM was mapped too aggressively (to the SXKV map class) and two instances where HXCM was mapped too conservatively (to the HXFM and SXBG map classes). These errors were caused by either a misestimation of shrub cover or by HXCM occurring above the set elevation cut.

Two examples of the same HXCM field in Cataloochee Valley, North Carolina, showing before (left, June 22, 2016) and after (right, August 24, 2016) management activities were completed to maintain the historical setting of the area.

HXLD – Artificial Lake Drawdown Zone

The Artificial Lake Drawdown Zone (HXLD) map class represents the (*Diospyros virginiana*, *Platanus occidentalis*) / *Eupatorium serotinum* - *Diodia virginiana* Ruderal Wet Meadow Association (CEGL003910) in the USNVC. This herbaceous vegetation map class occurs along the edges of the major reservoirs on the south edge of the Park in drought years and during reservoir maintenance. The HXLD map class is exceptionally rare within the Park covering 9.6 ha (0.005% of GRSM).

Although always occurring in the same area throughout the years, the herbaceous vegetation that defines HXLD may be absent in any particular year dependent on water levels in the reservoir. The year the project imagery was captured, the reservoirs were drawn down for maintenance exposing extensive areas for vegetation colonization. Because of the location where HXLD occurs and the lack of competing map classes, mappers were provided with a very consistent mapping protocol of short, red herbaceous vegetation in the project imagery positioned along the edge of manmade reservoirs.

The HXLD map class was mapped very consistently. The AA process discovered no new instances of the HXLD map class, and no instances of HXLD were confused with a different map class.

An example of the HXLD map class showing the young herbaceous vegetation in the bed of Abrams Creek where the creek enters the then (June 2017) drawn-down Chilhowie Lake reservoir in Tennessee.

MSDH – Standing Dead Hemlock Forest

The Standing Dead Hemlock Forest (MSDH) map class represents a map-special vegetation type in areas formerly dominated be eastern hemlock (*Tsuga canadensis*). The MSDH map class does not classify to any vegetation types in the USNVC. This map class occurs in the Park over areas formerly forested by eastern hemlock. The MSDH map class is rare within the Park covering 61.1 ha (0.03% of GRSM).

This map class represents areas that were once closed-canopy evergreen forests completely dominated by eastern hemlock. About 15 years ago, eastern hemlock dominated vast stretches of the Park; however, various non-native insects have nearly eliminated this species from GRSM. The few remaining stands are actively being treated to protect them from the insects. Most of the eastern hemlock-dominated forests have since succeeded into other vegetation types, with a few exceptions. In these rare places where the vegetation community is in flux, a diverse mix of young deciduous tree species have emerged from a thick blanket of great laurel (*Rhododendron maximum*). However, during this project, these tree species did not classify to a vegetation association but probably will in 10 years or less.

In the project imagery, MSDH presents as a "ghost forest" because of the large number (more than 30 per hectare) of very large, standing-dead eastern hemlocks over thick great laurel, often with some deciduous tree regeneration. No other forest had this combination of characteristics.

The MSDH map class was mapped very consistently. The AA process discovered no new instances of the MSDH map class, and no instances of MSDH were confused with a different map class.

An example MSDH map class showing many large, standing-dead eastern hemlock (*Tsuga canadensis*) over a thick layer of great laurel (*Rhododendron maximum*) with some young deciduous trees.

CFFP – Fraser Fir Plantation

The Fraser Fir Plantation (CFFP) map class represents native Fraser fir (*Abies fraseri*) planted as a genetic reserve for the Park in the Purchase Knob area and is classified as the cultural type Native Miscellaneous Southern Conifer Plantation Cultural Subtype (CST008544) in the USNVC. This map class was only found in the Purchase Knob area of the Park. This cultural map class is exceptionally rare within the Park covering 1.5 ha (0.0007% of GRSM).

This map class is defined by areas of native Fraser fir planted in rows and actively managed to maintain a potential breeding stock of trees for Park management and research purposes.

Because the CFFP map class is a cultural vegetation map class, CFFP was not assessed for accuracy.

An example of the CFFP map class showing planted Fraser fir (*Abies fraseri*) in the Purchase Knob area in North Carolina.

CHAV – Herbaceous Agricultural Vegetation

The Herbaceous Agricultural Vegetation (CHAV) map class represents the Herbaceous Agricultural Vegetation Cultural Subclass (CSC02) in the USNVC and depicts fields planted to agricultural crops. This map class is primarily present in the lower elevations within the Park. This cultural map class is extremely rare within the Park covering 15.2 ha (0.007% of GRSM).

This map class is defined by areas planted and managed for agricultural crops. During the field reconnaissance effort only hayfields were noted, but rotational crops such as corn and soybean could be possible. What ties this map class together is the consistent presentation of a monoculture of similar-aged plants occurring in rows, which denotes active agriculture and is clearly visible in improved hayfields. The few fields noted as CHAV could rotate among row crops, hay, and fallow fields; therefore, all fields of this type within the Park were mapped per presentation at the date of the project imagery. Consequently, areas mapped as CHAV could now be HXCM and vice versa, depending on where in the fallow-planted cycle the field is.

Because the CHAV map class is a cultural vegetation map class, CHAV was not assessed for accuracy.

An example of the CHAV map class along the Foothills Parkway in Tennessee, showing a hayfield with large round bales in the background.

CBRN – Barren Land

The Barren Land (CBRN) map class represents the Herbaceous & Woody Developed Vegetation Cultural Subclass (CSC03) in the USNVC and depicts unvegetated lands disturbed by human activity. The CSC03 cultural subclass is shared with the CDVL map class. The CBRN map class is widely scattered around the perimeter of the Park. This cultural map class is uncommon within the Park covering 274.4 ha (0.1% of GRSM).

The CBRN map class is defined by areas actively undergoing development or modification that leaves large areas denuded of vegetation (which will not be planted to a crop). This map class is generally transitory in nature because the class is being actively modified for some sort of human activity, such as construction. For GRSM, the main source of CBRN is exceptionally transitory and already gone from the landscape. In 2015, while project imagery was being collected, Fontana Dam was undergoing maintenance, and the reservoir was drawn down creating a large ring of unvegetated land around the margin of Fontana Lake reservoir. This area is now submerged again.

Because the CBRN map class is a cultural vegetation map class, CBRN was not assessed for accuracy.

No visual example is available for the CBRN map class.

CDVL – Developed Land

The Developed Land (CDVL) map class represents the Herbaceous & Woody Developed Vegetation Cultural Subclass (CSC03) in the USNVC and depicts areas managed or maintained as infrastructure including everything from maintained grass in picnic areas to industrial infrastructure surrounding flood-control dams. The CSC03 cultural subclass is shared with the CBRN map class. The CDVL map class is widely scattered around the edges of the Park in some of the culturally maintained areas, but is otherwise absent from the interior spaces. This map class is uncommon within the Park covering 986.3 ha (0.5% of GRSM).

The CDVL map class is mostly defined by areas where people reside, work, travel, or recreate. The features of CDVL are generally permanent, though management choices to develop infrastructure or to reduce impervious surface coverage or type could be initiated. The CDVL map class also applies to power-line corridors where shrub and tree growth are periodically managed to keep power lines clear of obstruction.

Because the CDVL map class is a cultural vegetation map class, CDVL was not assessed for accuracy.

Two examples of the CDVL map class showing different aspects of this map class with the Oconaluftee Visitor Center (left) and an elk (*Cervus elaphus*) crossing U.S. Route 441 (right), both in North Carolina.

NRSL – Rock Slide

The Rock Slide (NRSL) map class represents areas recently affected (respective to date of project imagery) by large erosion events (landslides) that have stripped the landscape down to bedrock; revegetation had not yet occurred by date of project-imagery collection. The NRSL map class does not classify to any vegetation types in the USNVC. This map class generally occurs on very steep slopes at the top of mountains in GRSM. However, one instance involves about 2 miles of Balsam Corner Creek that was "bulldozed" during a convective cloudburst rain event (severe rainstorm) during 2013 that dropped several inches of rain on the area in 1 hour. The NRSL map class is extremely rare within the Park covering 16.4 ha (0.008% of GRSM).

Because the NRSL map class is an unvegetated non-USNVC map class, NRSL was not assessed for accuracy. No visual example is available for the NRSL map class.

NFPW – Flowing and Ponded Water

The Flowing and Ponded Water (NFPW) map class represents open water that is unvegetated or otherwise not covered by surrounding vegetation. The NFPW map class does not classify to any vegetation types in the USNVC. The interior of GRSM has very little open-water areas, and most of the NFPW map class that is mapped within the interior of the Park is confined to the largest rivers and reservoirs. Most of the cover for this map class is the Fontana Lake reservoir that forms much of the south boundary of the Park. The NFPW map class is common within the Park covering 1,609.5 ha (0.8% of GRSM).

Because the NFPW map class is an unvegetated non-USNVC map class, NFPW was not assessed for accuracy.

Two examples of the NFPW map class showing the broad and shallow bed of Deep Creek in North Carolina (left), and the vast surface of Fontana Lake reservoir in North Carolina (right).

Table B-3. Map classification listing, sorted alphabetically by map-class code, used for the Great Smoky Mountains National Park vegetation mapping project.

Map-class code	Map-class name
CBRN	Barren Land
CDVL	Developed Land
CFFP	Fraser Fir Plantation
CHAV	Herbaceous Agricultural Vegetation
FAEC	Appalachian Evergreen Shrub Cove Forest
FAHC	Appalachian Herbaceous Cove Forest
FAWP	Southern Appalachian White Pine Forest
FBGP	Southern Appalachian Beech Gap
FBHH	Blue Ridge Hemlock - Northern Hardwood Forest
FCES	Chestnut Oak / Evergreen Shrub Forest
FFFS	Fraser Fir / Mixed Shrub Forest
FFMH	Mixed Hardwood Floodplain Forest
FHEO	High-Elevation Oak Forest
FNHH	Northern Hardwood High-Elevation Forest
FOHM	Mixed Oak / Mixed Shrub and Herb Forest
FOWP	Mixed Oak - White Pine Forest
FROH	Ridge-and-Valley Oak - Hardwood Forest
FSFD	Red Spruce - Fraser Fir Forest (Deciduous Shrub Type)
FSFE	Spruce - Fir / Evergreen Shrub Forest
FSHE	Red Spruce - Northern Hardwood Forest (Shrub Type)
FSHH	Red Spruce - Northern Hardwood Forest (Herb Type)
FUSP	Upland Sweetgum - Red Maple Pond
FXAH	Appalachian Ruderal Hardwood Forest
FXBL	Ruderal Black Locust Forest
FXNS	Ruderal Norway Spruce Forest
FXSG	Ruderal Sweetgum Forest

Table B-3 (continued). Map classification listing, sorted alphabetically by map-class code, used for the Great Smoky Mountains National Park vegetation mapping project.

Map-class code	Map-class name
FXSH	Southern Appalachian Ruderal Acidic Mixed Hardwood Forest
FXTW	Ruderal Tuliptree - Walnut Forest
FXWP	Ruderal Eastern White Pine Forest
HBAS	Southern Appalachian High-Elevation Rocky Summit (Anakeesta Type)
HGBF	Grassy Bald (Southern Grass Type)
HLAG	Low-Elevation Acidic Glade (Grass Type)
HSCP	Smartweed - Cutgrass Beaver Pond
HSGF	Graminoid and Forb Rocky Summit
HXCM	Cultivated Grassland
HXCR	Ruderal Common Rush Marsh
HXFM	Grazed Montane Grassland / Fire Meadow
HXLD	Artificial Lake Drawdown Zone
MSDH	Standing Dead Hemlock Forest
NFPW	Flowing and Ponded Water
NRSL	Rock Slide
SBMH	Southern Appalachian Mixed Heath Bald
SDAB	Southern Appalachian Hybrid Deciduous Azalea Bald
SFCB	Floodplain Canebrake
SGHO	Montane Grape Opening
SHBT	High-Elevation Blackberry Thicket
SMRT	Montane Rhododendron Thicket
SSAS	Southeastern Alder Swamp
SXBG	Ruderal Blackberry - Greenbrier Shrub Thicket
SXKV	Ruderal Kudzu Vineland
WTMH	Blue Ridge Table Mountain Pine - Pitch Pine Woodland (High-Elevation Type)
WYPO	Yellow Pine - (Dry Oak) Woodland

Appendix C: Accuracy Assessment Field Manual

Field Manual
For Accuracy Assessment
Sampling

National Park Service
Vegetation Mapping Inventory Program

Great Smoky Mountains National Park
Summers 2017–2020

Prepared for
U.S. Department of the Interior
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Prepared by
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Contents

A. THE BASIC FRAMEWORK FOR VEGETATION DESCRIPTION

Vegetation Physiognomy, Floristics, and Environment

The U.S. National Vegetation Classification (USNVC) is a vegetation classification that integrates floristic and physiognomic criteria, along with some environmental criteria, to define vegetation units. The upper levels of the USNVC hierarchy use formation concepts that are based on dominant and diagnostic growth forms that reflect the environment at global to continental scales. The formation concept has a long tradition in vegetation classification. In the revised USNVC, the formation concept is treated primarily as a physiognomic unit guided by ecological considerations, but importantly, it is open to some floristic input from lower levels. The midlevels are based on dominant and diagnostic growth forms and compositional similarity reflecting biogeography and continental to regional environmental factors. The lower levels (L7 and L8) are based on diagnostic and/or dominant species and compositional similarity reflecting local to regional environmental factors. The field sampling design emphasizes collecting data on all three sets of criteria. Field teams gather data on (1) dominant species, (2) dominant growth forms, and (3) environmental factors. Physiognomic and structural information are needed for the dominant and uppermost layers of vegetation. Location and environmental data are needed to confirm or explain floristic classification decisions.

Floristic information is the leading criteria for the alliance and association units that are being used to check the vegetation map at Great Smoky Mountains National Park (GRSM). These units are based on total species composition of a stand, as represented by a sampling unit. Thus, floristics and physiognomy must be described across all strata (or layers) of vegetation. Information on dominant and diagnostic species is collected across these layers to confirm the classification of the vegetation at accuracy assessment (AA) observation sites.

Cover of Species, Including by Strata

In addition to the simple presence of growth forms and species in an AA site, a measure of their abundance or dominance is needed. The USNVC gives consideration to the presence and abundance of species and to growth forms. Percent cover is the most widely accepted measure of species abundance or dominance because (1) it can be applied to all species, whether aquatic, herb, grass, shrub, or tree; (2) it is relatively easy to estimate in the field; and (3) it is a reliable and accurate measure for the purposes of classification.

Because the USNVC is an integrated physiognomic-floristic hierarchy, information on species percent cover should be collected within the context of the vertical strata in the AA site. In this way, major species dominants can be link to the dominant growth forms, and diagnostic species patterns can be assessed in the different layers of vegetation. In addition, older datasets that only contain information on a single stratum (e.g., only tree layer data) can still be compared to the percent cover data of that stratum.

Environmental Factors

Although primary classification decisions are based on floristic composition and physiognomy, final decisions about vegetation classes are often made in the context of information on environmental or local site factors. Indeed, habitat features are often valuable in making decisions about the diagnostic

value of species and they are useful in completing descriptions of vegetation types and using those descriptions to answer management or research questions (e.g., value as habitat to certain species or suitability for trails). Habitat features may help explain the vegetation pattern or provide additional criteria for the vegetation field key. For this reason, a variety of ecological or habitat factors are recommended to be collected, including at minimum: slope, elevation and aspect, topographic position, and evidence of disturbances. Wherever possible, "picklists" are provided to ensure consistency and ease of data entry. The information is rarely technical in nature, thus facilitating data collection in the field.

B. PROJECT AND AA SITE DESCRIPTION OVERVIEW

This section provides field teams with general instructions and guidelines for completing fieldwork for a given project area. The information gives the "how-to" for decision making in collecting data. Detailed, field-by-field coding conventions are provided for each of the primary data forms.

Field Sampling Strategy

Field sites are pre-selected based on the total area of each map class and corresponding associations. Sites are selected randomly using Geospatial Modeling Environment suite of tools and are spaced according to the minimum mapping unit (MMU) of a particular map class. Up to three AA observation sites are permissible in any single mapped polygon. Sampling will be done after navigating to the pre-selected AA points. Once at the site, the field crew should make sure to consider an area equal to the MMU when making classification decisions. The MMU for GRSM is 0.5 hectares (ha) (~1.2 acres) for most map units and 0.25 ha (~0.6 acres) for some map units (the MMU for each site will be noted on the field maps and within the AA point file attribution for the GPS unit). **The mapping team has not mapped vegetation units at scales smaller than 0.25 ha and thus it is critical that the AA field team does not consider smaller vegetation units either.** A circle with a radius of 40 meters (m) is 0.5 ha; a circle with a radius of 28 m is 0.25 ha. Once the field team is at the correct site and has scouted out an area equal to the MMU, they will begin to collect field data.

It is helpful to remember that map classes are not necessarily the same thing as vegetation associations. Map polygons are drawn and AA points are selected based on map classes. The field crew will assess the vegetation at an AA site and assign it to a vegetation association based on the field key to vegetation associations of GRSM. At GRSM, many, but not all, map classes are equivalent to vegetation associations. In most cases, this difference will not be important, or even apparent, to the field crew. One possible result of the difference that will affect the crews is that AA points may occasionally encompass more than one vegetation association. If a map class is composed of two similar vegetation associations, an AA point may be chosen that falls entirely within that single map class but on the border of two vegetation associations. In this event, the field crew should not move the AA point but should record data as normal and note that two vegetation associations are present, or the field crew should note that the site is intermediate between two associations and that crews are not confident only one association fits the site best (accomplished by recording both a primary and secondary best fit vegetation association name and corresponding 4-digit code on the data sheet and recording information on "confidence" and "fit" on the primary call).

Recognizing Strata and Growth Forms

A comprehensive vegetation description requires information on physiognomy, floristics, and environment. To standardize the collection of physiognomic information, collect information on the main strata of vegetation, including a list of species present in those strata. Because of the importance of using a standard approach to sampling vegetation strata, the issue is discussed in some detail here to ensure that subsequent discussions of field data collection are clear. A stratum is a layer of vegetation that includes all plant growth forms that occur within it. Plants are assigned to strata based on their predominant position or height in the stand, not by their taxonomy or mature growth form. Consequently, a tree species that has both seedlings and saplings in an AA site will be listed in several strata. In describing the vegetation physiognomy of an AA site for classification purposes, it is only necessary to capture the main features of the often-complex stand conditions rather than to describe the layering in the greatest possible detail.

In terrestrial environments, four basic vegetation strata should be recognized whenever they are present: tree, shrub, herb, and moss (sensu Fosberg 1961; the ground layer of mosses, liverworts, lichens, and algae). These four strata are needed to convey both the vertical distribution of overall cover and the predominant growth forms. Additionally, the four strata may be used to convey the abundance of each species in each stratum so as to provide a more detailed record of vegetation composition by strata. The four strata are defined as follows (see Figure C-1 for an example):

Tree stratum includes tall trees (single-stemmed woody plants, generally more than 5 m in height at maturity under optimal growing conditions). Very tall shrubs with tree-like form may also be included here, as may other growth forms such as lianas and epiphytes, and their contribution to the stratum can be further specified using the "growth form" field. For the **GRSM field form, this stratum is broken down into two categories: canopy and subcanopy.** Field teams should use the Height Scale and Cover Scale on the form. Estimate the stratum heights to the nearest height from the options provided, Canopy (20 m, 35 m, or >35 m) and Subcanopy (10 m or 20 m).

Shrub stratum includes shrubs (multiple-stemmed woody plants, generally less than 5 m in height at maturity under optimal growing conditions) and shorter trees (saplings) less than 5 m in height. As with the tree stratum, other growth forms present in this stratum may also be included; however, herbaceous growth forms should be excluded, as their stems often die back annually and do not have as consistent a height as woody growth forms. Field teams should use the Height Scale and Cover Scale on the form. Estimate the stratum heights to the nearest height from the options provided, Shrub (2 m or 5 m). (Some other projects differentiate tall shrub and short shrub strata.)

Herb stratum (also referred to as field or ground stratum) includes herbs (plants generally without woody stems and often dying back annually) often in association with low creeping semi-shrubs, vines, and nonwoody brambles (such as raspberries), as well as tree seedlings <1 m tall. Estimate the stratum heights to the nearest height from the options provided, Herbaceous (0.5 m, 1 m, or 2 m). Where herbs are entirely absent, it is still possible to recognize this

stratum if other very low woody or semi-woody growth forms are present. Prostrate shrubs are also included in this category (woody stemmed).

Nonvascular stratum (also referred to as moss, bryoid, or ground stratum) is defined entirely by mosses, lichens, liverworts, and algae that are growing on the ground. Ground-creeping vines, prostrate shrubs, and herbs should be treated in the herb stratum.

Epiphytes, vines, and lianas are treated where they are present within the strata defined above, not as separate strata.

Within each basic woody stratum, separate out substrata.

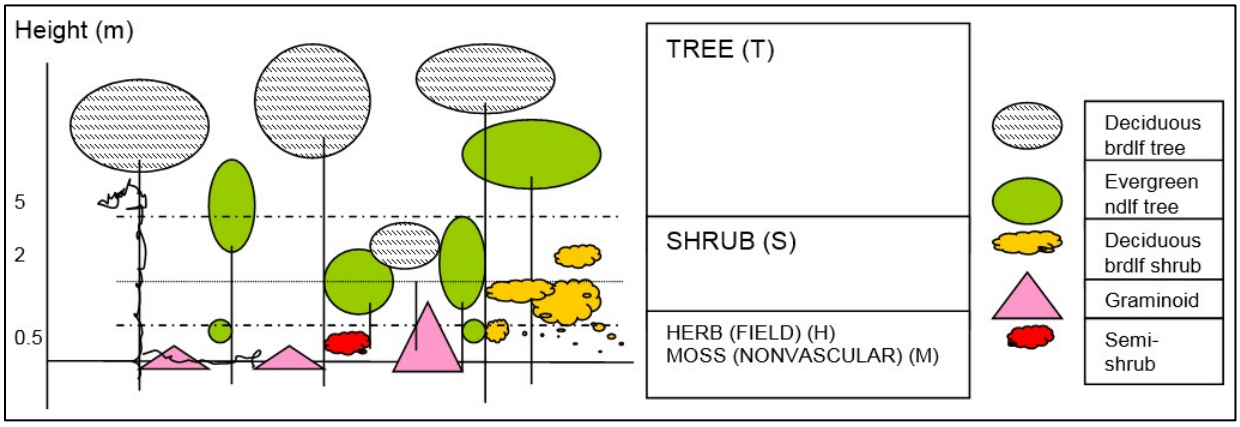

Figure C-1. Major strata (layers) recognized in terrestrial vegetation. Shown here are typical strata found in forests. brdf, broadleaf; ndlf, needleleaf

Measuring Species Abundance and Strata Using Percent Cover

Percent cover is a meaningful attribute for nearly all plant growth forms and allows their abundances to be evaluated in comparable terms. Percent cover can be defined generically as "the vertical projection of the crown or shoot area to the ground surface expressed as … percent of the reference area" (Mueller-Dombois and Ellenberg 1974). For our purposes, percent cover based on crown or shoot area is applied as canopy cover rather than foliar cover. Canopy cover is the percentage of ground covered by a vertical projection of the outermost perimeter of the natural spread of foliage of plants. Small openings within the canopy are included.

Canopy cover is the preferred method of collecting cover because it better estimates the "area that is directly influenced by the individuals of each species" (Daubenmire 1968), is easier than foliar cover to estimate from aerial photos, and is more likely to correlate with satellite image analysis. A classification based on canopy cover is better suited for mapping vegetation than one based on foliar cover. Strata cover should always be estimated on an absolute basis, and individual species cover should also be estimated as absolute cover rather than relative cover, which is taken relative to the absolute cover of the strata. If relative species cover is needed for later analysis, there is an easy conversion (relative cover for a species within a stratum equals absolute cover for that species in that stratum/absolute cover for the stratum).

C. ACCURACY ASSESMENT DIGITAL FORM

The Basics

The AA sites are not marked by defined boundaries. AA points are randomly selected in advance. Field teams navigate to the point using GPS, scout out the area briefly to get a feel for what the area is like, and record some general data to characterize it on an AA form.

Getting There

Depending on the project, the team may have a variety of base maps to work with to locate AA sites. In National Park Service Vegetation Mapping Inventory Program projects, field teams will have, at a minimum, an aerial photo with the AA points that they need to visit/sample. Polygons to be assessed will either be at a radius of 28 m (0.25-ha MMU) or 40 m (0.5-ha MMU). Linework between polygons will not generally appear on the maps, except in cases where the chosen AA point has a lower than typical buffer from the adjacent polygon. The team will navigate to each selected area using maps, the aerial photo(s), and global positioning system (GPS) units. If point maps are provided to the field crew(s), these maps may have roads and trails highlighted on them to help the team as well.

Before leaving for your site each week... check that the team has all the materials needed to complete the fieldwork (see Section E: Checklists for Field Teams).

Every morning... check the GPS receiver to make sure it is set to North American Datum of 1983 (NAD 83), that the batteries are charged or at a sufficient amount, replacement batteries are brought along, and the storage memory is sufficient for the day's work. Check the camera to ensure there is space for the day's work. If you are using a digital camera, verify that batteries and memory are sufficient. Make sure the iPad is charged and ready for the day's work. Also bring along paper datasheets in case the iPad stops working properly.

Location of the AA site... navigate to the exact coordinates of the target AA point. If it is not safe to position yourself at the exact coordinates (and assuming there is a clear line of sight to the AA point and that you can easily key the community type out and take data with a reasonable level of confidence), then get as close as possible, record the Universal Transverse Mercator (UTM) coordinates and UTM zone of your actual position, and then record the offset. The offset should be recorded as a direction (azimuth) and distance (in meters) from the UTM coordinates where you are standing to the target point you were originally aiming for.

Acceptable Reasons for dismissing an AA point (and information on how to document this)... Most AA sites at GRSM should be accessible. The only exceptions will be sites that end up being too close to roads, sites that are in areas too steep to navigate, or those that pose an immediate safety risk due to environmental conditions (e.g., significant amount of overhead snags). In order to determine if you can dismiss an AA point, please ask the following questions. If you answer yes to any of these questions, you should go to the second set of questions below:

- Does anyone on the team feel that accessing the AA site will be an unacceptable risk to their personal safety?

- To access the AA site, will you need to traverse unreasonably steep terrain?
- Will accessing the AA site require you to climb a fence (e.g., no gates)?
- Will accessing the AA site require you to navigate through water above your knees or cross a swift stream and there are no other means available to efficiently access the AA site (boat, etc.)?

If you answered yes to any of these questions, please answer the following question to determine if you can dismiss the AA point:

- Without traveling to the center of the AA site, do you have clear line of sight to the AA point and can you easily key the community type out and take data with a reasonable level of confidence?

If you answered yes to one of the first four questions and yes to the question above, proceed with collecting point data remotely but make note in the sketch of your current position in relation to the AA site. Make sure to state the reasoning for the offset of the point in the space provided. Also, you will take the GPS data from where you are standing and need to explain in the notes that the GPS data are where you observed the AA point, not at the intended site center.

If you answered "no" to the last question, throw out the point.

VERY IMPORTANT: AS SOON AS YOU DISMISS AN AA POINT, PLEASE TEXT, CALL, OR EMAIL THE PROJECT SUPERVISOR WITH THE POINT NAME, REASON FOR DISMISSING IT, AND ANY OTHER USEFUL INFORMATION SO THAT WE CAN WORK WITH UMESC STAFF TO ASSIGN A NEW AA POINT TO REPLACE THIS ONE AS SOON AS POSSIBLE. During GRSM AA field efforts, the project supervisor will be Troy Evans.

Once There—The Basic Procedures for Field Data Collection

Survey 123 Digital Data Form

Open Survey 123 on the iPad and open GRSM_AA_Site_Form. Fill in all data fields which are described in the Explanations of Data Fields on Digital Form section.

Determine and Record the AA Site Location

Using the GPS receiver, field teams determine and record the UTM coordinates. Field teams also record the GPS estimated error. If the team cannot get a GPS reading with sufficient accuracy (estimated error at or below 10 m), they should mark the location they were at as precisely as they can on the aerial photo maps they have or they should continue to let the GPS run in the background while taking data to see if they can get the estimated error value lower (in meters). If a map was marked up, the exact location coordinates can be estimated later. Note on the field form that this will be required and attach the map to the form.

Identifiers/Locators

Complete the information for any fields that are not already completed. The AA point code is pre-determined by the mapping group and should be recorded on the form. The GPS code will be named

as F plus the four-digit AA code (e.g. F0168) and will be entered into the GPS unit when collecting data.

Taking Vegetation Photographs

Teams should take six photos at each AA site. The first photo is of the AA field form after recording, at a minimum, the AA point number and UTM coordinates. The next four photos should be in the four cardinal directions (N, E, S, W) starting with north. Because the photos taken in the cardinal directions may not capture the feel of the area, take one photo that best represents the sample area. Make sure to mark on the field form the photo numbers or the order of the photos taken in the blank marked "photo #s" (order of photos should be "photo of form, N, E, S, W, representative photo").

All photos should be taken in RAW/TIFF format for archival purposes. These photo types are space-intensive, so care should be taken to ensure adequate space on the memory card before starting the field day.

Record Environmental Description

Environmental information for AA sites is relatively simple. Record the unvegetated surface substrate, elevation, slope angle, aspect (slope direction), topographic position, environmental factors affecting the vegetation of the area, and evidence of disturbance. Instruments and their use are covered during training so that all field crews are collecting these data the same way.

Sketch of Observation Area

The sketch is very important because it can often be used to help later reviewers better understand the environmental context. With this information, the reviewer may be able to give the final call a higher confidence value or conversely may use the information to make a different call than the original data collector. Make sure that each AA site has a sketch, especially for areas where you perceive that multiple associations exist in one MMU. Be sure to follow sketch instructions listed on the GRSM AA field form. It is important to remember to draw the polygon line when relevant to provide confidence that the correct area was assessed. When collecting the data through Survey 123, draw the sketch on a piece of paper and take a picture of it to add to the field photos (will be photo #7).

Complete Vegetation Description

Substrata (e.g., canopy tree and subcanopy tree) are standard for the National Park Service Vegetation Mapping Inventory Program and are seated within the basic strata.

Provide the prevailing height of the top of each stratum.

Record the species information in the following manner:

1) Begin by entering the most dominant species and record its presence in each stratum, if applicable. Continue entering in species that occur in the AA site.
2) Collect any unknown dominant or diagnostic species (see details below) and label each bag or sheet containing the specimen with the AA site code and a unique identifier corresponding to the code on the form (e.g., *Carex* #1, Fern #2).
3) Provide an estimated cover for each species in each stratum:

a) Estimate individual species absolute canopy percent covers for the stratum (e.g., *Quercus rubra* in the Tree Canopy);
b) Add up species covers within the stratum and compare to total stratum cover. Sort out any discrepancies, recognizing that overlap can occur between species and layers and that you are only recording cover of dominant species (e.g., cover of minor species will not appear on the data sheet and absolute cover of all dominant species may be lower or higher than total stratum cover in many cases).

4) Check your list of species to be sure that a species was not forgotten.

Some Guidance on Estimating Cover

The percent cover of the stratum is the total vertical projection of the canopy cover of all species collectively onto the ground, not the sum of the individual percent covers of all species in the stratum.

Plants are assigned to strata based on their predominant position or height in the stand, not by their taxonomy or mature growth form. Consequently, a tree species that has both seedlings and saplings in an AA site could be listed in several strata.

Epiphytes and lianas are handled by listing them in the strata in which they occur. Thus, epiphytes and lianas may also be listed on the field form in more than one stratum.

The herb stratum (herb, herbaceous, or field stratum) includes all low woody, semi-woody plants, or creeping vines, where these woody plants and vines overlap in height with the herbs. This inclusion is a compromise among strata based strictly on height versus growth form. Field teams may find it helpful to create a checklist of dwarf-shrubs, semi-woody shrubs, or vines that are to be recorded along with herbaceous plants as part of the herb stratum.

The nonvascular stratum (sometimes called moss, bryoid, or ground stratum) is reserved strictly for very low growing cryptogams (mosses, lichens, liverworts, algae, and bacteria), even where herbs or woody plants may be reduced to very short heights.

Collecting Specimens

Field teams should have sufficient botanical expertise to identify most species encountered in the project area. If the team cannot identify a plant to species, they should record it on the form as "unknown species 1," "unknown species 2," "unknown *Carex* sp. 1," etc. They can record associated cover class and other data for the unknown as they would for any other species. They can then do one of two things:

a. If the team needs the species identified right away because it appears to be dominant or diagnostic (they will be seeing it all over the place or it is much more common in this particular vegetation type than in others), they can take a sample of the species with as much of the plant as possible, especially intact flower or fruiting parts, if present. Place the sample in a bag or on a sheet and label the bag or sheet with the AA site code and the name used on the data form (e.g., *Carex* sp.1). A member of the team should then try to key it out.

b. If plant specimens must be saved for identification beyond a few days, they must be dried, pressed in an assigned plant press, and labeled with the AA site code and name used for identification. Correct use of the plant press will be covered during training. Specimens should then be brought to Twin Creeks for identification, and the park botanist will decide if the specimen will be kept as a collection.

If possible, store specimens in a cool, dry place until ready to be pressed. Bagged specimens will keep fresh longer in the refrigerator or ice chest until pressed or identified. A judgment must be made early on regarding species that should be identified in the field versus those that can wait. Common plants recurring in many AA sites are best keyed in the field, whereas those encountered rarely or at very low cover may be keyed later when manuals are likely to be readily accessible. A quick prioritization of what to key and what to press may be made based on the recurrence of the species in samples and on the cover-class estimate of the species in a particular AA site. Field teams should mark the specimen tag with its cover class estimate and any notes helpful in identification such as "tall shrub" or "wetland plant," as well as its unique identifying number for the vegetation sample. If pressed specimens begin to build up, teams should let their project supervisor know. The supervisor/coordinator can then take steps to have some of the plant specimens identified.

Classifying the AA Site

Once all data have been collected at an AA site, the field team needs to provide a classification name for the vegetation. Field teams will have a vegetation field key to work through to decide on the classification. Typically, physiognomy and floristics will both be important to place a community within the USNVC. Any confusion about how to classify the AA site or if the vegetation field key does not work well should be noted on the AA form. The concepts of "confidence" and "fit" allow users to record how confident they are that the classification name decided on is correct based on their experience in the field, as well as how well the association "keyed out" or fit. Additionally, if the vegetation field key does not work well at a specific site, the AA crew should still record a best fit vegetation association based on the vegetation field key. Again, make note that the vegetation type assigned to the site is the "best fit" and score the fit as low, and score the confidence as high, medium, or low depending upon their professional opinion.

If the vegetation field key fails repeatedly in one area, please look at and make notes on how the vegetation field key may be improved to provide the best outcome and suggest changes to the project supervisor/coordinator.

Before Leaving Each AA Site

Before heading off, be sure to check the form to be sure all the categories have been completed. In particular:

1. Double check that the coordinates are recorded.
2. Look over the various strata categories to be sure there are cover values for all strata and species within each stratum.
3. Look over the dominant species lists to be sure none were missed that were called out or observed.

4. Review the descriptive fields that summarize the overall impression of the stand (environmental comments, unvegetated surface, representativeness, adjacent vegetation communities, fit, confidence, and classification comments). If these have not been filled out, now is a good time.
5. Check the equipment list to be sure nothing is left behind, and all flagging has been cleaned up.

When completing a site, if any required fields are left blank or incomplete, the fieldworker will not be allowed to save the site and move to the next form.

Final Steps Including Turning in Data Each Week

Perhaps the most important step, turning in data in a timely manner, will help complete the project on time and on budget. Turning in data in a timely manner will also keep loss of data at a minimum because data that pile up can often disappear or become disorganized creating confusion and data loss. The following are the key steps to complete before and during the handoff of data:

1. At the end of each field day/multi-day trip, all forms will be uploaded to ArcGIS Online as multiple feature layers. Double check that the sites you visited are the sites that were uploaded and the number uploaded is correct. If not, make note of the site that did not upload properly.
2. At least once a week, Tom Colson will download all feature layers from ArcGIS Online to the SQL server where the AA vegetation data will be kept. Tom will also provide the elevation in feet to each site. Photos will need to be converted to both JPEG and TIFF as per the image management standard operating procedure.
3. Initial QA/QC will be conducted by Troy Evans before sending data to NatureServe for the final vegetation association call.
4. Download an Excel CSV file from the SQL database and zip the AA site photos.
5. Email an Excel csv file containing the AA data and site photos to Tom Govus, tgovus@ellijay.com at NatureServe biweekly. Once the AA sites are updated, send the CSV file back to Troy Evans at troy_evans@nps.gov also biweekly.
6. Email the CSV file provided by Tom Govus to Stephanie Sattler at UMESC, ssattler@usgs.gov, so that completed points can be kept tracked of, what points were thrown out, and what points are not completed.

Explanations of Data Fields on Digital Form

LOCATION INFORMATION

AA Point Code

Number for the AA point, from AA map or from pre-loaded list in the GPS unit. In the GPS unit, these are called IDENT, and are projected in NAD 83 UTM Zone 17N.

GPS Point Code

Code for the coordinates saved in the GPS. At GRSM, use F plus a four-digit number. For instance, if the AA point code is 203, then the GPS point code would be “F0203.” The AA point code and

GPS point code should be really close to one another unless the crew had GPS difficulties or was required to offset the point because of issues with access.

Survey Date

Record the date the survey was taken; month, day, year.

AA Site Time

Record the time data collection was started at the site (military format).

Field Team

Record the names of surveyors, with team leader listed first. The team leader is the person most responsible for the quality of the data recorded on the form and the first person to which questions about the data will be addressed. Full names should be recorded (full first and last name).

Photo of Form

Circle whether or not photos of the first page of the AA form were taken.

Photo Numbers

Record the individual photo numbers or range of photo numbers, as listed in the camera, taken at each specific site. There should be at least six photos collected. The first six photos are, in order, (1) the beginning of the AA form after at least the point number, UTM, and date have been recorded, (2) in cardinal directions from the GPS point clockwise starting with north (N, E, S, W), and (3) one or more photos that best represent the assessed area. In an ideal entry, the photo #s form would read "photo of form, N, E, S, W, representative photo."

UTM X

Record UTM X coordinates, also called "easting," using a GPS unit.

UTM Y

Record UTM Y coordinates, also called "northing," using a GPS unit.

GPS Point is Intentionally Offset

If the crew cannot reach the pre-set coordinates of the AA point, note the reason (e.g., dangerous slope, water, private property) then record the azimuth and estimated distance to the pre-set coordinates. If the assessment area around the original coordinates is visible and the crew feels they can accurately classify the vegetation (binoculars may be useful for this) they should continue with the form.

ENVIRONMENTAL DESCRIPTION

Unvegetated Surface Substrate

Estimate ground or surface cover to the nearest percentage by each category (Table C-1). For surface features not provided on this list, use the "other" category and note the feature. Cover estimates should sum to 100%. In cases where moss, lichen, sand, or litter thinly covers the rock, ignore the less significant cover and record the total cover of rock. Rock and sand definitions are from Brady and Weil (2002).

Slope

Measure the slope in degrees using a clinometer or estimate using a compass that contains a slope-measuring device. Circle the appropriate slope degree that best describes each site.

Aspect

Measure the slope aspect (direction of slope) using a compass (be sure to correct for the magnetic declination). Note: all compasses should be pre-set to an average declination for the park and thus, readings from the compasses carried by the field teams may be directly noted. Circle the aspect that best describes the site.

Topographic Position

Take time to observe where the AA site is on the landscape. Then, choose one of the following categories: Interfluve (Ridge/summit/crest), High slope, Midslope, Lowslope, Toeslope, Low level (terrace), or channel bed.

Table C-1. Percent value descriptions to record unvegetated surface values within an accuracy assessment site.*

Value	Description
Percent Bedrock	Percent of surface that is exposed bedrock
Percent Loose Boulders and Stone	Percent of surface that is exposed gravel/pebble (2–75 mm), cobble (75–256 mm) and stone/boulder (>256 mm).
Percent Leaf Litter / Organic Matter	Percent of surface that is litter
Percent Decaying Wood	Percent of surface that is wood >1 cm diameter
Percent Water	Percent of surface that is covered in water
Percent Mineral Soil / Sand	Percent of surface that is occupied by bare mineral soil or eolian or alluvial sand deposits (0.05 mm to 2.0 mm)
Other	–

* mm, millimeter; cm, centimeter

Environmental Comments

Enter any additional noteworthy comments on the environmental setting. This field can be used to describe stand history such as fire events (date since last fire or evidence of severity), as well as other disturbance or stand regeneration factors. On the form it states, "(Characteristics that affect vegetation—e.g., if the site is a wetland, indicate type of hydrology, e.g., seepage wetland, temporarily flooded stream bottom, seasonally flooded pond, etc.; topographic position, landform, evidence of natural and human disturbance, successional status, stand maturity, etc.)."

Evidence of Disturbance

Select any disturbances that are observed in the AA site. More than one disturbance can be selected. Provide the disturbance seen if not provided in the given list. This field was added to the datasheet in the summer of 2018.

Sketch of Observation Area

Draw a sketch of the observation area using aerial view or transect view, or both. Indicate north arrow, where GPS coordinates were collected, whether an offset point was needed, locations and bearings of photo points, AA site orientation, roads, trails, polygon lines if applicable, and any other distinctive features of the vegetation (e.g., transitions to different vegetation types, landscape features). Site need not be circular if constrained by map guidelines.

VEGETATION STRUCTURE

Stratum, Strata Maximum Height, Cover Values by Strata

For all of the strata that are present, record the height and total cover. You should use the Height Scale and Cover Scale on the form. Estimate the stratum heights to the nearest height from the options provided.

Record the maximum cover class for each vertical vegetation stratum indicated on the table. The heights in the right column indicate the maximum height accepted for each stratum, Canopy (20 m, 35 m, >35 m), Subcanopy (10 m, 20 m), Shrub (2 m, 5 m), and Herbaceous (0.5 m, 1 m, or 2 m). The lowest stratum contains all woody plants <0.5 m tall and all herbaceous plants, regardless of height. Choose a default maximum height for each stratum.

VEGETATION COMPOSITION

List the absolute cover of all species with a cover value of more than 10% with a special emphasis on the species that you would consider to be characteristic of the vegetation at the AA site. You may list additional species that are present at lower cover if they are deemed to be diagnostic. Write the species in the "Species" column; indicate whether you consider it a diagnostic species for the purpose of classification, noting if you have collected it for further identification work. Record species cover in the following cover classes:

P <5%, 01 = 5–15%, 02 = 15–25%, 03 = 25–35%, 04 = 35–45%, 05 = 45–55%, 06 = 55–65%, 07 = 65–75%, 08 = 75–85%, 09 = 85–95%, 10=>95%

Species

Record the full taxon name or use the code from the list supplied by GRSM.

Diagnostic Species

Place a check mark or X if the taxon is diagnostic of the vegetation community. A diagnostic taxon is any species whose relative constancy or abundance differentiates one vegetation type from another.

Total Cover

Record the total cover of the taxon throughout the entirety of the assessed area.

Canopy Layer
Record the total cover of the taxon in the tree canopy over the assessed area.

Subcanopy Layer
Record the total cover of the taxon in the subcanopy over the assessed area.

Shrub Layer [note: this field form only accommodates one shrub stratum]
Record the total cover of the taxon in the shrub stratum over the assessed area.

Herbaceous Layer
Record the total cover of the taxon in the herbaceous layer over the assessed area.

Nonvascular Layer
Record the total cover of the taxon in the nonvascular layer over the assessed area.

Specimen Collected
Place a "Y" if a specimen was collected for this species.

Confidence in ID
Note the confidence in the identification of the taxon as H=High, M=Medium, or L=Low.

POINT ASSESSMENT

Representativeness
Is the area of the vegetation being assessed around the AA point at least equivalent to 1 MMU? Indicate whether the vegetation is homogeneous, very patchy, or transitional between two types. Note whether there are other vegetation communities within or near the assessment area.

Fit
Rated as HIGH, MEDIUM, or LOW - record both how easily the vegetation at the AA site was keyed to a vegetation community AND how confident the field crew is that the vegetation communities they keyed the site to actually fits the vegetation at the site. Vegetation at a site may fit the vegetation field key well but the final classification may not match the community well or vice versa. If you chose MEDIUM or LOW, record how well the vegetation field key worked to classify the vegetation around the AA point. Especially important is to note any difficulties or questions encountered in classifying the AA site, either because of confusion with the vegetation field key or disturbance/heterogeneity around the AA site.

Primary Field Call
This is the vegetation community that best fits the AA site based on the vegetation field key. Please use the Common Name of the vegetation association as listed in the vegetation field key and record the ELCODE (e.g., CEGL00XXXX) of association that best fits the site.

Secondary Field Call
If the vegetation of the area at the AA site seems intermediary between two types or if there are two associations prominent within the assessment area, record the second best fit in this field and record

the ELCODE (e.g., CEGL00XXXX) and common name of that association as listed in the vegetation field key. Small inclusions of a second association in the assessment area are ignored.

D. ACCURACY ASSESSMENT PAPER FORM

*****This is the hard copy version of the digital form and will only be used if an iPad will not record data while in the field.**

The Basics

The AA sites are not marked by defined boundaries. AA points are randomly selected in advance. Field teams navigate to the point using GPS, scout out the area briefly to get a feel for what the area is like, and record some general data to characterize it on an AA form.

Getting There

Depending on the project, the team may have a variety of base maps to work with to locate AA sites. In National Park Service Vegetation Mapping Inventory Program projects, field teams will have, at a minimum, an aerial photo with the AA points that they need to visit/sample. Polygons to be assessed will either be at a radius of 28 m (0.25-ha MMU) or 40 m (0.5-ha MMU). Linework between polygons will not generally appear on the maps, except in cases where the chosen AA point has a lower than typical buffer from the adjacent polygon. The team will navigate to each selected area using maps, the aerial photo(s), and GPS. If point maps are provided to the field crew(s), these maps may have roads and trails highlighted on them to help the team as well.

Before leaving for your site each week... check that the team has all the materials needed to complete the fieldwork (see Section E: Checklists for Field Teams).

Every morning... check the GPS receiver to make sure it is set to NAD 83, that the batteries are charged or at a sufficient amount, replacement batteries are brought along, and the storage memory is sufficient for the day's work. Check the camera to ensure there is space for the day's work. If you are using a digital camera, verify that batteries and memory are sufficient.

Location of the AA site... navigate to the exact coordinates of the target AA point. If it is not safe to position yourself at the exact coordinates (and assuming there is a clear line of sight to the AA point and that you can easily key the community type out and take data with a reasonable level of confidence), then get as close as possible, record the Universal Transverse Mercator (UTM) coordinates and UTM zone of your actual position, and then record the offset. The offset should be recorded as a direction (azimuth) and distance (in meters) from the UTM coordinates where you are standing to the target point you were originally aiming for.

Acceptable Reasons for dismissing an AA point (and information on how to document this)... Most AA sites at GRSM should be accessible. The only exceptions will be sites that end up being too close to roads, sites that are in areas too steep to navigate, or those that pose an immediate safety risk due to environmental conditions (e.g., significant amount of overhead snags).

In order to determine if you can dismiss an AA point, please ask the following questions. If you answer yes to any of these questions, you should go to the second set of questions below:

- Does anyone on the team feel that accessing the AA site will be an unacceptable risk to their personal safety?
- To access the AA site, will you need to traverse unreasonably steep terrain
- Will accessing the AA site require you to climb a fence (e.g., no gates)?
- Will accessing the AA site require you to navigate through water above your knees or cross a swift stream and there are no other means available to efficiently access the AA site (boat, etc.)?

If you answered yes to any of these questions, please answer the following question to determine if you can dismiss the AA point:

- Without traveling to the center of the AA site, do you have clear line of sight to the AA point and can you easily key the community type out and take data with a reasonable level of confidence?

If you answered yes to one of the first four questions and yes to the question above, proceed with collecting point data remotely but make note in the sketch of your current position in relation to the AA site. Make sure to state the reasoning for the offset of the point in the space provided. Also, you will take the GPS data from where you are standing and need to explain in the notes that the GPS data are where you observed the AA point, not at the intended site center.

If you answered "no" to the last question, throw out the point.

VERY IMPORTANT: AS SOON AS YOU DISMISS AN AA POINT, PLEASE TEXT, CALL, OR EMAIL THE PROJECT SUPERVISOR WITH THE POINT NAME, REASON FOR DISMISSING IT, AND ANY OTHER USEFUL INFORMATION SO THAT WE CAN WORK WITH UMESC STAFF TO ASSIGN A NEW AA POINT TO REPLACE THIS ONE AS SOON AS POSSIBLE. During GRSM AA field efforts, the project supervisor will be Troy Evans.

Once There—The Basic Procedures for Field Data Collection

Determine and Record the AA Site Location

Using the GPS receiver, field teams determine and record the UTM coordinates. Field teams also record the GPS estimated error. If the team cannot get a GPS reading with sufficient accuracy (estimated error at or below 10 m), they should mark the location they were at as precisely as they can on the aerial photo maps they have or they should continue to let the GPS run in the background while taking data to see if they can get the estimated error value lower (in meters). If a map was marked up, the exact location coordinates can be estimated later. Note on the field form that this will be required and attach the map to the form.

Identifiers/Locators

Complete the information for any fields that are not already completed. The AA point code is pre-determined by the mapping group and should be recorded on the form. The GPS code will be named as F plus the four-digit AA code (e.g. F0168) and will be entered into the GPS unit when collecting data.

Taking Vegetation Photographs

Teams should take six photos at each AA site. The first photo is of the AA field form after recording, at a minimum, the AA point number and UTM coordinates. The next four photos should be in the four cardinal directions (N, E, S, W) starting with north. Because the photos taken in the cardinal directions may not capture the feel of the area, take one photo that best represents the sample area. Make sure to mark on the field form the photo numbers or the order of the photos taken in the blank marked "photo #s" (order of photos should be "photo of form, N, E, S, W, representative photo").

All photos should be taken in RAW/TIFF format for archival purposes. These photo types are space-intensive, so care should be taken to ensure adequate space on the memory card before starting the field day.

Record Environmental Description

Environmental information for AA sites is relatively simple. Record the unvegetated surface substrate, elevation, slope angle, aspect (slope direction), topographic position, environmental factors affecting the vegetation of the area, and evidence of disturbance. Instruments and their use are covered during training so that all field crews are collecting these data the same way.

Sketch of Observation Area

The sketch is very important because it can often be used to help later reviewers better understand the environmental context. With this information, the reviewer may be able to give the final call a higher confidence value or conversely may use the information to make a different call than the original data collector. Make sure that each AA site has a sketch, especially for areas where you perceive that multiple associations exist in one MMU. Be sure to follow sketch instructions listed on the GRSM AA field form. It is important to remember to draw the polygon line when relevant to provide confidence that the correct area was assessed.

Complete Vegetation Description

Substrata (e.g., canopy tree and subcanopy tree) are standard for the National Park Service Vegetation Mapping Inventory Program and are seated within the basic strata.

Provide the prevailing height of the top of each stratum.

Having decided on the strata, record the species information in the following manner:

1. Begin by simply listing the dominant 1–4 species (plus any diagnostic species) observed in each of the main layers.
2. Collect any unknown dominant or diagnostic species (see details below) and label each bag or sheet containing the specimen with the AA site code and a unique identifier corresponding to the code on the form (e.g., *Carex* #1, Fern #2).
3. When the list appears complete (including all the dominant plant species found in each stratum of the vegetation), begin estimating cover. For each stratum:
    a. Estimate total absolute cover of the stratum (Tree Canopy, Herbaceous, etc.);

b. Estimate individual species absolute canopy percent covers for the stratum (e.g., *Quercus rubra* in the Tree Canopy);

c. Add up species covers within the stratum and compare to total stratum cover. Sort out any discrepancies, recognizing that overlap can occur between species and layers and that you are only recording cover of dominant species (e.g., cover of minor species will not appear on the data sheet and absolute cover of all dominant species may be lower or higher than total stratum cover in many cases).

4. Check your list of species to be sure that each is clearly written out. Whenever possible, use the species names that match the taxonomic authority for your project.

Some Guidance on Estimating Cover

The percent cover of the stratum is the total vertical projection of the canopy cover of all species collectively onto the ground, not the sum of the individual percent covers of all species in the stratum.

Plants are assigned to strata based on their predominant position or height in the stand, not by their taxonomy or mature growth form. Consequently, a tree species that has both seedlings and saplings in an AA site could be listed in several strata.

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a. If the team needs the species identified right away because it appears to be dominant or diagnostic (they will be seeing it all over the place or it is much more common in this particular vegetation type than in others), they can take a sample of the species with as much of the plant as possible, especially intact flower or fruiting parts, if present. Place the sample in a bag or on a sheet and label the bag or sheet with the AA site code and the name used on the data form (e.g., *Carex* sp.1). A member of the team should then try to key it out.

b. If plant specimens must be saved for identification beyond a few days, they must be dried, pressed in an assigned plant press, and labeled with the AA site code and name used for identification. Correct use of the plant press will be covered during training. Specimens should then be brought to Twin Creeks for identification, and the park botanist will decide if the specimen will be kept as a collection.

If possible, store specimens in a cool, dry place until ready to be pressed. Bagged specimens will keep fresh longer in the refrigerator or ice chest until pressed or identified. A judgment must be made early on regarding species that should be identified in the field versus those that can wait. Common plants recurring in many AA sites are best keyed in the field, whereas those encountered rarely or at very low cover may be keyed later when manuals are likely to be readily accessible. A quick prioritization of what to key and what to press may be made based on the recurrence of the species in samples and on the cover-class estimate of the species in a particular AA site. Field teams should mark the specimen tag with its cover class estimate and any notes helpful in identification such as "tall shrub" or "wetland plant," as well as its unique identifying number for the vegetation sample. If pressed specimens begin to build up, teams should let their project supervisor know. The supervisor/coordinator can then take steps to have some of the plant specimens identified.

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Once all data have been collected at an AA site, the field team needs to provide a classification name for the vegetation. Field teams will have a vegetation field key to work through to decide on the classification. Typically, physiognomy and floristics will both be important to place a community within the USNVC. Any confusion about how to classify the AA site or if the vegetation field key does not work well should be noted on the AA form. The concepts of "confidence" and "fit" allow users to record how confident they are that the classification name decided on is correct based on their experience in the field, as well as how well the association "keyed out" or fit. Additionally, if the vegetation field key does not work well at a specific site, the AA crew should still record a best fit vegetation association based on the vegetation field key Again, make note that the vegetation type assigned to the site is the "best fit" and scored the fit as low, and score the confidence as high, medium, or low depending upon their professional opinion.

If the vegetation field key fails repeatedly in one area, please look at and make notes on how the vegetation field key may be improved to provide the best outcome and suggest changes to the project supervisor/coordinator.

Before Leaving Each AA Site

Before heading off, be sure to check the forms to be sure all of the categories have been completed. In particular:

1. Double check that the coordinates are recorded.
2. Look over the various strata categories to be sure there are cover values for all strata and species within each stratum.
3. Look over the dominant species lists to be sure none were missed that were called out or observed.

4. Review the descriptive fields that summarize the overall impression of the stand (environmental comments, unvegetated surface, representativeness, adjacent vegetation communities, fit, confidence, and classification comments). If these have not been filled out, now is a good time.
5. Check the equipment list to be sure nothing is left behind, and all flagging has been cleaned up.

Once the data recorder is confident that the form is complete, they will need to initial the form as "Field Checked." This helps ensure that each form is confirmed as complete while still at the site.

Final Steps Including Turning in Data Each Week

Perhaps the most important step, turning in data in a timely manner will help complete the project on time and on budget. Turning in data in a timely will also keep loss of data at a minimum because data that pile up can often disappear or become disorganized creating confusion and data loss. The following are the key steps to complete before and during the handoff of data:

1. At the end of each field day/multi-day trip, all forms are to be scanned as a pdf and emailed to troy_evans@nps.gov. Each form will need to be sent separately to facilitate proper electronic data management.
2. At least once a week, download all GPS points you collected as well as all photo images to the GRSM network, and arrange in the proper file-structure. Photos will need to be converted to both JPEG and TIFF as per the image management standard operating procedure.
3. Upload scanned field forms, field photos and GPS file and send to Troy Evans at GRSM.
4. Initial QA/QC will be conducted by Troy Evans before sending data to NatureServe for the final vegetation association call.
5. Download an Excel CSV file from the SQL database and zip the AA site photos.
6. Email an excel CSV file containing the AA data and site photos to Tom Govus, tgovus@ellijay.com at NatureServe biweekly. Once the AA sites are updated, send the csv file back to Troy Evans at troy_evans@nps.gov also biweekly.
7. Email the CSV file provided by Tom Govus to Stephanie Sattler at UMESC, ssattler@usgs.gov, so that completed points can be kept tracked of, what points were thrown out, and what points are not completed.

Explanations of Data Fields on AA Form

LOCATION INFORMATION

State

Circle either TN or NC.

AA Point Code

Number for the AA point, from AA map or from pre-loaded list in the GPS unit. In the GPS unit, these are called IDENT, and are projected in NAD 83 UTM Zone 17N.

GPS Point Code

Code for the coordinates saved in the GPS. At GRSM, use F plus a four-digit number. For instance, if the AA point code is 203, then the GPS point code would be "F0203." The AA point code and GPS point code should be really close to one another unless the crew had GPS difficulties or was required to offset the point because of issues with access.

Survey Date

Record the date the survey was taken; month, day, year.

AA Point Time

Record the time data collection was started at the site (military format).

Field Team

Record the names of surveyors, with team leader listed first. The team leader is the person most responsible for the quality of the data recorded on the form and the first person to which questions about the data will be addressed. Full names should be recorded (full first and last name).

Photo of Form

Circle whether or not photos of the first page of the AA form were taken.

Photo Numbers

Record the individual photo numbers or range of photo numbers, as listed in the camera, taken at each specific site. There should be at least six photos collected. The first six photos are, in order, (1) the first page of the AA form after at least the point number, UTM, and date have been recorded, (2) in cardinal directions from the GPS point clockwise starting with north (N, E, S, W), and (3) one or more photos that best represent the assessed area. In an ideal entry, the photo #s form would read "photo of form, N, E, S, W, representative photo."

Datum/UTM Zone

For GRSM, all GPS units should be collecting data in NAD 83 UTM Zone 17N, and these values are printed on the form. If for some reason location must be collected in a different format, then write in the Datum/Coordinate System here.

GPS Estimated Error

Note the estimated error of your GPS Unit (in meters) and whether GPS averaging was used.

UTM X

Record UTM X coordinates, also called "easting," using a GPS unit.

UTM Y

Record UTM Y coordinates, also called "northing," using a GPS unit.

Iterations/GPS Score

Averaging points is generally advisable, and required if the estimated error is >10 m. If you average, please do so ideally for 100 iterations (in older GPS units) or until 100% confidence is achieved (in newer units).

GPS Point is Intentionally Offset

If the crew cannot reach the pre-set coordinates of the AA point, note the reason (e.g., dangerous slope, water, private property) then record the azimuth and estimated distance to the pre-set coordinates. If the assessment area around the original coordinates is visible and the crew feels they can accurately classify the vegetation (binoculars may be useful for this) they should continue with the form.

ENVIRONMENTAL DESCRIPTION

Elevation

Record the elevation in meters at which the GPS point was recorded using in NAD 83 UTM Zone 17N. Note the source used to calculate elevation. The GPS unit is preferred as a source for elevation over the digital raster graphic (DRG) maps, but the latter can be used if necessary. If the GPS was not placed at ground level when recording, subtract the height (in meters) that the GPS was at when recording to get the correct elevation for that location.

Unvegetated Surface Substrate

Estimate ground or surface cover to the nearest percentage by each category (Table C-2). For surface features not provided on this list, use the "other" category and note the feature. Cover estimates should sum to 100%. In cases where moss, lichen, sand, or litter thinly covers the rock, ignore the less significant cover and record the total cover of rock. Rock and sand definitions are from Brady and Weil (2002).

Table C-2. Percent value descriptions to record unvegetated surface values within an accuracy assessment site.*

Value	Description
Percent Bedrock	Percent of surface that is exposed bedrock
Percent Loose Boulders and Stone	Percent of surface that is exposed gravel/pebble (2–75 mm), cobble (75–256 mm) and stone/boulder (>256 mm).
Percent Leaf Litter / Organic Matter	Percent of surface that is litter
Percent Decaying Wood	Percent of surface that is wood >1 cm diameter
Percent Water	Percent of surface that is covered in water
Percent Mineral Soil / Sand	Percent of surface that is occupied by bare mineral soil or eolian or alluvial sand deposits (0.05 mm to 2.0 mm)
Other	–

* mm, millimeter; cm, centimeter

Slope

Measure the slope in degrees using a clinometer or estimate using a compass that contains a slope-measuring device. Circle the appropriate slope degree that best describes each site.

Aspect

Measure the slope aspect (direction of slope) using a compass (be sure to correct for the magnetic declination). Note: all compasses should be pre-set to an average declination for the park and thus, readings from the compasses carried by the field teams may be directly noted. Circle the aspect that best describes the site.

Topographic Position

Take time to observe where the AA site is on the landscape. Then, choose one of the following categories: Interfluve (Ridge/summit/crest), High slope, Midslope, Lowslope, Toeslope, Low level (terrace), or channel bed.

Environmental Comments

Enter any additional noteworthy comments on the environmental setting. This field can be used to describe stand history such as fire events (date since last fire or evidence of severity), as well as other disturbance or stand regeneration factors. On the form it states, "(Characteristics that affect vegetation—e.g., if the site is a wetland, indicate type of hydrology, e.g., seepage wetland, temporarily flooded stream bottom, seasonally flooded pond, etc.; topographic position, landform, evidence of natural and human disturbance, successional status, stand maturity, etc.)."

Evidence of Disturbance

Select any disturbances that are observed in the AA site. More than one disturbance can be selected. Provide the disturbance seen if not provided in the given list.

Sketch of Observation Area

Draw a sketch of the observation area using aerial view or transect view, or both. Indicate north arrow, where GPS coordinates were collected, whether an offset point was needed, locations and bearings of photo points, AA site orientation, roads, trails, and any other distinctive features of the vegetation (e.g., transitions to different vegetation types, landscape features). Site need not be circular if constrained by map guidelines.

VEGETATION STRUCTURE

Stratum, Strata Maximum Height, Cover Values by Strata

For all of the strata that are present, record the height and total cover. You should use the Height Scale and Cover Scale on the form. Estimate the stratum heights to the nearest height from the options provided.

Record the maximum cover class for each vertical vegetation stratum indicated on the table. The heights in the right column indicate the maximum height accepted for each stratum, Canopy (20 m, 35 m, >35 m), Subcanopy (10 m, 20 m), Shrub (2 m, 5 m), and Herbaceous (0.5 m, 1 m, or 2 m). The lowest stratum contains all woody plants <0.5 m tall and all herbaceous plants, regardless of height. Choose a default maximum height for each stratum.

VEGETATION COMPOSITION

List the absolute cover of all species with a cover value of more than 10% with a special emphasis on the species that you would consider to be characteristic of the vegetation at the AA site. You may list

additional species that are present at lower cover if they are deemed to be diagnostic. Write the species in the "Species" column; indicate whether you consider it a diagnostic species for the purpose of classification, noting if you have collected it for further identification work. Record species cover in the following cover classes:

P <5%, 01 = 5–15%, 02 = 15–25%, 03 = 25–35%, 04 = 35–45%, 05 = 45–55%, 06 = 55–65%, 07 = 65–75%, 08 = 75–85%, 09 = 85–95%, 10=>95%

Species

Record the full taxon name or use the code from the list supplied by GRSM.

Diagnostic Species

Place a check mark or X if the taxon is diagnostic of the vegetation community. A diagnostic taxon is any species whose relative constancy or abundance differentiates one vegetation type from another.

Total Cover

Record the total cover of the taxon throughout the entirety of the assessed area.

Canopy Layer

Record the total cover of the taxon in the tree canopy over the assessed area.

Subcanopy Layer

Record the total cover of the taxon in the subcanopy over the assessed area.

Shrub Layer [note: this field form only accommodates one shrub stratum]

Record the total cover of the taxon in the shrub stratum over the assessed area.

Herbaceous Layer

Record the total cover of the taxon in the herbaceous layer over the assessed area.

Nonvascular Layer

Record the total cover of the taxon in the nonvascular layer over the assessed area.

Specimen Collected

Place a "Y" if a specimen was collected for this species.

Confidence in ID

Note the confidence in the identification of the taxon as H=High, M=Medium, or L=Low.

<u>POINT ASSESSMENT</u>

Representativeness

Is the area of the vegetation being assessed around the AA point at least equivalent to 1 MMU? Indicate whether the vegetation is homogeneous, very patchy, or transitional between two types. Note whether there are other vegetation communities within or near the assessment area.

Fit

Rated as HIGH, MEDIUM, or LOW - record both how easily the vegetation at the AA site was keyed to a vegetation community AND how confident the field crew is that the vegetation communities they keyed the site to actually fits the vegetation at the site. Vegetation at a site may fit the vegetation field key well but the final classification may not match the community well or vice versa. If you chose MEDIUM or LOW, record how well the vegetation field key worked to classify the vegetation around the AA point. Especially important is to note any difficulties or questions encountered in classifying the AA site, either because of confusion with the vegetation field key or disturbance/heterogeneity around the AA site.

Primary Field Call

This is the vegetation community that best fits the AA site based on the vegetation field key. Please use the Common Name of the vegetation association as listed in the vegetation field key and record the ELCODE (e.g., CEGL00XXXX) of association that best fits the site.

Secondary Field Call

If the vegetation of the area at the AA site seems intermediary between two types or if there are two associations prominent within the assessment area, record the second best fit in this field and record the ELCODE (e.g., CEGL00XXXX) and common name of that association as listed in the vegetation field key. Small inclusions of a second association in the assessment area are ignored.

E. CHECKLISTS FOR FIELD TEAMS

Planning for the Day

1. Safety and sustenance issues (food, minimum 2L water, proper clothing, first-aid kit).
2. Field communications: Submit a daily field itinerary to project supervisor (Troy Evans), and carry a fully-charged park radio. Radios are to be on while in the field, and the crew must know the proper repeater to use for the area they are in.
3. Check GPS (batteries, available memory, waypoints, below MMU assessment area polyline tracks, etc.).
4. Check digital camera (batteries, available memory).
5. Check list for all other field equipment.
6. Plan the day's mission before departure using the hardcopy AA point map with flagged points.

Planning for the Week

1. Check for all appropriate maps, aerial imagery (if available), and AA point maps.
2. Develop an estimate of reasonable expectations of AA sites to choose for each team broken up by day and based on an estimate of individual team's travel logistics for the week.
3. Develop plan for the week to sample all AA points in work area.
4. Balance items 2 and 3 in the "Planning for Day" list with the expected work schedule of the teams and ensure adequate time off and reduce overtime concerns.

5. Check for all necessary information for AA point maps for the zone and blank field forms.
6. Communication with management team and field teams.
7. All uncertainties dealt with (e.g., not able to get to some points, problems with interpreting map information, personnel issues, problems in interpreting classification/key, park-related logistics).
    a. Organization of field teams.
    b. Gather completed field forms (allow time for QA/QC and resolving questions about the forms).
    c. Obtain all plants not identified (allow time for plant identification).
    d. Were there any questions about the polygons visited during the week?
    e. What was accomplished, what was not accomplished?
    f. Pass on the developments and questions to the management team on a regular basis. Do not let them build up too long.

Final Steps at Week's End

1. Update list of sampled AA sites.
2. Upload all GPS point data and photo data to GRSM Network.
3. Email datasheets to Tom Govus, tgovus@ellijay.com 601A Foster Street, Durham, NC 27701.

Field Materials

- AA point maps
- road/trail maps
- compass
- GPS receiver (checked daily to ensure that it is set correctly (to NAD 83)
- clinometer
- camera and batteries/memory card (allow at least six exposures per AA site)
- baggies
- pens/permanent markers
- AA forms, including some on waterproof paper
- classification report for the project
- vegetation field key
- loupe/magnifier for identifying plants
- botanical manuals

Appendix D: Accuracy Assessment Reconciliation

Contents

Explanation of Accuracy Assessment Reconciliation

This appendix presents the steps used to reconcile the vegetation map layer following the accuracy assessment (AA) analysis for the Great Smoky Mountains National Park (GRSM, also referred to as the "Park") vegetation mapping project. This process involved presenting to National Park Service (NPS) staff from GRSM a review of how and why vegetation map classes did not meet NPS Vegetation Mapping Inventory (VMI) Program standards, providing a suggestion for how to remedy the issue, and explaining the benefits and consequences of accepting the suggestion.

The standard set by the NPS VMI Program is that a map class be at least 80% accurate within the 90% confidence interval for the map class; the upper limit 90% confidence interval is abbreviated as (UL–CI). The map classes referenced in this appendix and what became of each map class are listed in Table D-1. The information listed in table D-1 helps to understand the process and maintain continuity with the final map classification for GRSM. Please reference Table D-1 for map class acronyms in this appendix only.

Table D-1. Original map-class codes that existed prior to accuracy assessment map reconciliation, linked to new map-class codes.*

Original map-class code	Original accuracy				Vegetation-type code(s)	New map-class code	New accuracy			
	Users' straight	Users' UL–CI	Producers' straight	Producers' UL–CI			Users' straight	Users' UL–CI	Producers' straight	Producers' UL–CI
FCDS	50%	67%	56%	73%	CEGL007267	FOHM	85%	93%	71%	80%
FOMH	61%	75%	43%	55%	CEGL006192 CEGL007230 CEGL007692 CEGL007720 CEGL007878 CEGL008567	FOHM	85%	93%	71%	80%
FAEC	57%	73%	50%	66%	CEGL007543 CEGL007693	FAEC	63%	77%	72%	86%
FSAH	9%	28%	50%	133%	CEGL007102 CEGL007136	FAEC	63%	77%	72%	86%
SBMH	33%	50%	100%	106%	CEGL003951 CEGL007876	SBMH	91%	98%	98%	102%
SBML	83%	96%	58%	72%	CEGL003814	SBMH	91%	98%	98%	102%
SBAB	0%	0%	0%	25%	CEGL003892	SHBT	81%	96%	100%	102%
SHBT	20%	40%	100%	117%	CEGL003893 CEGL004184	SHBT	81%	96%	100%	102%
SXHT	83%	105%	50%	71%	CEGL007293	SHBT	81%	96%	100%	102%
SMRT	40%	86%	67%	128%	CEGL003819	SMRT	50%	92%	100%	117%
SSRB	0%	50%	0%	0%	CEGL003849	SMRT	50%	92%	100%	117%

* Codes to vegetation types are presented by map class to complete the bridge between original and new map classes. UL–CI, Upper Limit–Confidence Interval

Table D-1 (continued). Original map-class codes that existed prior to accuracy assessment map reconciliation, linked to new map-class codes.*

Original map-class code	Original accuracy				Vegetation-type code(s)	New map-class code	New accuracy			
	Users' straight	Users' UL–CI	Producers' straight	Producers' UL–CI			Users' straight	Users' UL–CI	Producers' straight	Producers' UL–CI
FAEC	63%	77%	72%	86%	CEGL007102 CEGL007136 CEGL007543 CEGL007693	FAEC	63%	77%	72%	86%
FBHH	60%	76%	95%	106%	CEGL007861	FBHH	60%	76%	95%	106%
FCES	68%	82%	47%	60%	CEGL006271 CEGL006286 CEGL007691 CEGL008431	FCES	68%	82%	47%	60%
FSHH	90%	101%	60%	73%	CEGL006256	FSHH	90%	101%	60%	73%
FXAH	60%	76%	55%	70%	CEGL007219	FXAH	60%	76%	55%	70%
FXSH	63%	79%	76%	92%	CEGL008558	FXSH	63%	79%	76%	92%
FXTW	77%	91%	59%	73%	CEGL007184 CEGL007220 CEGL007221 CEGL007879	FXTW	77%	91%	59%	73%
FXWP	60%	76%	82%	98%	CEGL007944	FXWP	60%	76%	82%	98%

* Codes to vegetation types are presented by map class to complete the bridge between original and new map classes. UL–CI, Upper Limit–Confidence Interval

A. FCDS and FOHM

Confusion between the deciduous shrub chestnut oak (*Quercus montana*) forest FCDS and the deciduous shrub northern red oak (*Quercus rubra*) and white oak (*Quercus alba*) forest FOMH

Problem: Initially, mappers expected to be able to distinguish these two map classes based upon signature differences between chestnut oak over deciduous shrub and other oak species (*Quercus* spp.) over deciduous shrub. However, the AA process identified systematic confusion between FCDS and FOMH to such a degree that neither map class met VMI Program standards.

Suggestion: Collapse FCDS and FOMH into a single map class.

Consequences: From a management prospective, there is no expected difference between the FCDS and FOMH map classes. While having two map classes for these very common vegetation types was preferred, the degree of confusion was too severe.

Park Staff Decision: Accept collapse of FCDS and FOMH.

B. FAEC and FSAH

Confusion between the acidic cove forest FAEC and the eastern hemlock and eastern white pine forest FSAH

Problem: Initially, mappers expected to be able to distinguish these two map classes based upon where eastern hemlock (*Tsuga canadensis*) was being treated (per park records) and the amount of conifer found in the canopy. However, the AA process identified systematic confusion between FAEC and FSAH to such a degree that neither map class met VMI Program standards.

Suggestion: Collapse FAEC and FSAH into a single map class.

Consequences: Eastern hemlock has become a species of significant management concern following massive mortality caused by non-native insects. Collapsing these map classes would merge the very rare FSAH into the very common FAEC removing the ability of the Park to see where these remnant eastern hemlock stands occur in the vegetation map. However, park resource managers maintain maps of all eastern hemlock treatments so the consequences are minimal.

Park Staff Decision: Accept collapse of FAEC and FSAH.

C. SBML and SBMH

Confusion between low elevation and high elevation heath balds

Problem: Initially, mappers and classifiers believed that a single elevation split would be sufficient to separate the low-elevation heath balds from the high-elevation heath balds. The AA process consistently found the low-elevation heath bald map class to nearly the highest elevations in the Park and well within the same elevation zone of the high-elevation heath bald map class.

Suggestion: Collapse SBMH and SBML into a single map class.

Consequences: Collapsing these into a single map class will reduce the resolution of the map for different types of heath bald shrublands, but greatly increase the ability of the map to resolve the location of heath bald shrublands in the Park.

Park Staff Decision: Accept collapse of SBMH and SBML.

D. SBAB, SHBT, and SXHT and CEGL004184

Significant confusion between high-elevation blackberry species (*Rubus* spp.) map classes SBAB, SHBT, and SXHT and inclusion of CEGL004184 in mapped areas

Problem: Initially, mappers expected to be able to distinguish these three map classes based upon signature, vegetation height, and location. However, the AA process identified systematic confusion between the three such that none of the map classes individually met VMI Program standards. Finally, the AA process identified that the short-statured trees of CEGL004184 could be confused for SHBT, with CEGL004184 not placed in any map class.

Suggestion: Collapse SBAB, SHBT, and SXHT and add CEGL004184.

Consequences: Collapsing these map classes would result in the loss of the ability to discern different types of high-elevation blackberry species shrub map classes and add in ruderal hawthorn species (*Crataegus* spp.).

Park Staff Decision: Accept collapse of SBAB, SHBT, and SXHT and addition of CEGL004184.

E. SMRT and SSRB

The very rare SSRB map class is mapped poorly

Problem: The AA process determined that SMRT was mapped to VMI Program standards, but SSRB was not and was confused with SMRT. Both map classes are dominated by great laurel (*Rhododendron maximum*) and mappers believed the classes could be separated based on landscape position and hydrologic influence, but the classes could not be separated.

Suggestion: Collapse SMRT and SSRB.

Consequences: The one known location of SSRB was mapped on hydrology and signature only with no instances of SSRB known from the Park. Collapsing SMRT and SSRB introduces different hydrologic regimes into one map class, but the map class remains dominated by the same evergreen shrub species.

Park Staff Decision: Accept collapse of SMRT and SSRB.

F. CEGL008438 and SXBG

Discovery of CEGL008438 in SXBG

Problem: During the AA process, one instance of the association CEGL004178 was discovered. Mappers did not encounter CEGL004178 during the field reconnaissance efforts and interpreted the signature as an odd variant of HCRM. While ecologically different than the common reed

(*Phragmites australis*) dominated HCRM, CEGL004178 is also dominated by the tall graminoid, swamp sawgrass (*Cladium mariscus*). While not ideal, the AA process suggests that placing CEGL004178 in the HCRM map class is warranted given that it was not discovered in any other map class.

Suggestion: Add CEGL008438 to SXBG.

Consequences: Having a rare non-ruderal association of management interest mixed into a map class dominated by a common ruderal vegetation association.

Park Staff Decision: Accept addition of CEGL008438 into SXBG.

G. FAEC

FAEC has users' accuracy below VMI Program standards

Problem: There was general confusion in mapping FAEC, a low-elevation acidic cove forest map class that is dominated by mixed mesic hardwoods or codominated by mixed mesic hardwoods and eastern white pine (*Pinus strobus*). The confusion is broad and shallow for users' accuracy (seven different map classes), but concentrated on the mesic oak over deciduous shrub forest (FOMH), ruderal acidic hardwood forest (FXAH), and ruderal eastern white pine forest (FXWP) map classes. The map class has a UL–CI users' accuracy of 77%, which is below the VMI Program standard. Unfortunately, the confusion does not present a simple way to bring the users' accuracy into compliance without grouping at least two other very different map classes together.

Suggestion: Accept a slightly lower accuracy on FAEC to preserve other, well-mapped map classes.

Consequences: Map users will need to understand that while the FAEC map class primarily represents low-elevation acidic cove forests, it does include some mesic oak, ruderal hardwoods, and ruderal eastern white pine.

Park Staff Decision: Accept lower users' accuracy on FAEC.

H. FBHH

FBHH has users' accuracy below VMI Program standards

Problem: There was general confusion in mapping FBHH, a high-elevation northern hardwood forest over evergreen shrub map class. The confusion is broad and shallow for users' accuracy (seven different map classes), but concentrated on the mixed red spruce (*Picea rubens*) - northern hardwood forest over evergreen shrub (FSHE) map class and the mixed red spruce - northern hardwood forest over deciduous shrub (FSHH) map class. The map class has a UL–CI users' accuracy of 76%, which is below the VMI Program standard. Unfortunately, the confusion does not present a simple way to bring the users' accuracy into compliance without grouping at least two other very different map classes together.

Suggestion: Accept a slightly lower accuracy on FBHH to preserve other, well-mapped map classes.

Consequences: Map users will need to understand that while the FBHH map class primarily represents high-elevation northern hardwood forest over evergreen shrub, it does include some mixed red spruce - northern hardwood forest at its upper elevation range.

Park Staff Decision: Accept lower users' accuracy on FBHH.

I. FCES

FCES has producers' accuracy below VMI Program standards

Problem: There was general confusion in mapping FCES, a chestnut oak (*Quercus montana*) over evergreen heath map class. The confusion is broad and shallow for users' accuracy (nine different map classes), but concentrated on the mesic oak over deciduous shrub forest (FOMH) map class and the ruderal southern hardwood over evergreen shrub forest (FXSH) map class. The map class has a UL–CI users' accuracy of 60%, which is below the VMI Program standard. Unfortunately, the confusion does not present a simple way to bring the users' accuracy into compliance without grouping at least two other very different map classes together.

Suggestion: Accept a lower accuracy on FCES to preserve other, well-mapped map classes.

Consequences: Map users will need to understand that while the FCES map class primarily represents chestnut oak over evergreen heath, it does include the co-occurring mesic oak over deciduous shrub forest and the ruderal southern hardwood over evergreen shrub forest map classes.

Park Staff Decision: Accept lower users' accuracy on FCES.

J. FSHH

FSHH has producers' accuracy below VMI Program standards

Problem: There was general confusion in mapping FSHH, a mixed red spruce (*Picea rubens*) - northern hardwood forest over deciduous shrub map class. The confusion is broad and shallow for producers' accuracy (six different map classes), but concentrated on the red spruce forest over deciduous shrub (FSFD) map class and the mixed red spruce - northern hardwood forest over evergreen shrub (FSHE) map class. The map class has a UL–CI producers' accuracy of 73%, which is below the VMI Program standard. Unfortunately, the confusion does not present a simple way to bring the users' accuracy into compliance without grouping at least two other very different map classes together.

Suggestion: Accept a lower accuracy on FSHH to preserve other, well-mapped map classes.

Consequences: Map users will need to understand that while the FSHH map class primarily represents mixed red spruce - northern hardwood forest over deciduous shrub, it does include the co-occurring red spruce and red spruce -hardwood forest map classes.

Park Staff Decision: Accept lower users' accuracy on FSHH.

K. FXAH

FXAH has users' and producers' accuracies below VMI Program standards

Problem: There was general confusion in mapping FXAH, a ruderal mixed hardwood forest map class. The confusion is broad and shallow for both users' (five different map classes) and producers' accuracy (six different map classes), but concentrated on a mixed oak and mixed deciduous shrub forest (FOMH) map class and a ruderal tuliptree (*Liriodendron tulipifera*) and black walnut (*Juglans nigra*) forest (FXTW) map class. The map class has a UL–CI producers' accuracy of 76% for users' accuracy and 70% for producers' accuracy, which are below the VMI Program standard. Unfortunately, the confusion does not present a simple way to bring the users' accuracy into compliance without grouping at least two other very different map classes together.

Suggestion: Accept a lower accuracy on FXAH to preserve other, well-mapped map classes.

Consequences: Map users will need to understand that while the FXAH map class primarily represents ruderal mixed hardwood forest, it does include the co-occurring mixed oak and mixed deciduous shrub forest and ruderal tuliptree and walnut forest map classes.

Park Staff Decision: Accept lower users' and producers' accuracy on FXAH.

L. FXSH

FXSH has users' accuracy below VMI Program standards

Problem: There was specific confusion in mapping FXSH, a ruderal southern hardwood over evergreen shrub forest map class. The confusion is centered on a chestnut oak (*Quercus montana*) over evergreen shrub forest (FCES) map class and pushes the UL–CI users' accuracy for users' down to 79%, which is slightly below the VMI Program standard. While remedying the confusion could be achieved by merging these two map classes, it would introduce a generally mesic, hardwood, ruderal map class into a generally xeric, chestnut oak, non-ruderal map class.

Suggestion: Accept a slightly lower accuracy on FXSH to preserve other, well-mapped map classes.

Consequences: Map users will need to understand that while the FXSH map class primarily represents ruderal southern hardwood over evergreen shrub forest, it does include examples of the co-occurring xeric, chestnut oak, non-ruderal forest map class.

Park Staff Decision: Accept lower users' accuracy on FXSH.

M. FXTW

FXTW has producers' accuracy below VMI Program standards

Problem: There was general confusion in mapping FXTW, a tuliptree (*Liriodendron tulipifera*) and black walnut (*Juglans nigra*) forest map class. The confusion is broad and shallow for producers' accuracy (nine different map classes), but concentrated on the ruderal mixed hardwood forest (FXAH) map class. The map class has a UL–CI producers' accuracy of 73%, which is below the VMI Program standard. Unfortunately, the confusion does not present a simple way to bring the

users' accuracy into compliance without grouping at least two other very different map classes together.

Suggestion: Accept a lower accuracy on FXTW to preserve other, well-mapped map classes.

Consequences: Map users will need to understand that while the FXTW map class primarily represents ruderal tuliptree and black walnut forest, it does include the co-occurring ruderal mixed hardwood forest map class.

Park Staff Decision: Accept lower users' accuracy on FXTW.

N. FXWP

FXWP has users' accuracy below VMI Program standards

Problem: There was general confusion in mapping FXWP, a ruderal eastern white pine (*Pinus strobus*) forest map class. The confusion is broad and shallow for users' accuracy (six different map classes), but concentrated on the acidic hardwood over evergreen shrub cove forest (FAEC) map class. The map class has a UL–CI producers' accuracy of 76%, which is below the VMI Program standard. Unfortunately, the confusion does not present a simple way to bring the users' accuracy into compliance without grouping at least two other very different map classes together.

Suggestion: Accept a lower accuracy on FXWP to preserve other, well-mapped map classes.

Consequences: Map users will need to understand that while the FXWP map class primarily represents ruderal eastern white pine forest, it does include the co-occurring acidic hardwood over evergreen shrub cove forest map class.

Park Staff Decision: Accept lower users' accuracy on FXTW.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 133/176872, July 2021

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