



Digital Vegetation Database and Map for Big South Fork National River and Recreation Area

Final Report



Photo of the Big South Fork River at Big South Fork National River and Recreation Area.

© THOMAS JORDAN

Digital vegetation database and map for Big South Fork National River and Recreation Area: Final report

Science Report NPS/SR—2024/199

Thomas Jordan, Marguerite Madden

Center for Remote Sensing and Mapping Science (CRMS) Department of Geography
The University of Georgia
Athens, GA 30602-2503

Please cite this publication as:

Jordan, T., and M. Madden. 2024. Digital vegetation database and map for Big South Fork National River and Recreation Area: Final report. Science Report NPS/SR—2024/199. National Park Service, Fort Collins, Colorado. <https://doi.org/10.36967/2305475>

The National Park Service Science Report Series disseminates information, analysis, and results of scientific studies and related topics concerning resources and lands managed by the National Park Service. The series supports the advancement of science, informed decisions, and the achievement of the National Park Service mission.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible and technically accurate.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, US Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the US Government.

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.

This report is available in digital format from the [National Park Service DataStore](#) and the [Natural Resource Publications Management website](#). If you have difficulty accessing information in this publication, particularly if using assistive technology, please email irma@nps.gov.

Contents

	Page
Figures.....	iv
Tables.....	vi
Abstract.....	vii
Acknowledgments.....	viii
Introduction.....	1
Objectives	3
Study Area	4
Requirements	7
Collateral Datasets	11
Photogrammetric Operations	12
Scanning	12
Ground Control and Pass Point Measurement.....	12
Aerotriangulation.....	14
Photointerpretation and Ground Truthing Operations	17
GIS Operations.....	27
Creating the Map Database	27
Quality Assurance/Quality Assessment	31
Final Products	33
GIS Databases	33
Map Products.....	33
Summary and Conclusion	36
Literature Cited	38
Appendix A. Vegetation Classification and Statistics for Big South Fork National River and Recreation Area.....	40
Appendix B. Digital Vegetation Maps of the Big South Fork National River and Recreation Area	57

Figures

	Page
Figure 1. Big South Fork National River and Recreation Area is located on the Cumberland Plateau in north-central Tennessee and southern Kentucky.....	4
Figure 2. Locations and extents of the various areas mapped for BISO, including the Legislated Boundary (green), and the Buffer Area (blue).	6
Figure 3. A portion of a 1:16,000 scale color infrared aerial photograph of the confluence of the Big South Fork (lower left) with its two major tributaries, New River (upper left) and Clear Fork (right), recorded on October 11, 2003 and used for photo interpretation of vegetation detail.	8
Figure 4. Generalized diagram showing photogrammetric, photointerpretation, and GIS operations used to map vegetation from aerial photographs by the CRMS.....	10
Figure 5. Well-defined natural and manmade features were used as pass points in overlapping images (yellow cross in circle symbols in the photos above).	13
Figure 6. The elevations of ground control points (GCPs) were determined from the 30-m digital elevation model (DEM) using a bilinear interpolation algorithm.....	14
Figure 7. Nine pass points per photo and additional GCPs are measured and transferred to adjacent photos in the flight line.	15
Figure 8. A mosaic of orthorectified 1:16,000-scale photographs of BISO was created for quality assurance and checking and to provide an image backdrop for the GIS database.....	15
Figure 9. Conducting a field survey of the vegetation prior to beginning detailed photo interpretation.	18
Figure 10. Field map for BISO used for field data collection with UTM grid, color orthophotos, roads, and rivers.	19
Figure 11. Example of a ground image showing overstory and understory vegetation along the Big South Fork River (NPS 2009).	20
Figure 12. CRMS Vegetation Classification System for BISO that combines classes of the National Vegetation Classification System (NVCS), modified NVCS classes, land uses and special modifiers (Section 1 — Forest Classes).	22
Figure 13. CRMS Vegetation Classification System for BISO that combines classes of the National Vegetation Classification System (NVCS), modified NVCS classes, land uses and special modifiers (Section 2 — Forest Classes (continued), Shrubland).	23

Figures (continued)

	Page
Figure 14. CRMS Vegetation Classification System for BISO that combines classes of the National Vegetation Classification System (NVCS), modified NVCS classes, land uses and special modifiers (Section 3 — Herbaceous, Additional Categories, Burn Rating Modifiers).	24
Figure 15. CRMS Vegetation Classification System for BISO that combines classes of the National Vegetation Classification System (NVCS), modified NVCS classes, land uses and special modifiers (Section 4 — Species and Additional Modifiers, Buffer Classes).	25
Figure 16. Sample scanned overlay showing vegetation polygons and CEGl code values.	27
Figure 17. Photo overlay depicting vegetation polygons and a 1-cm grid before and after corrections for relief displacement.....	28
Figure 18. Full overlay that has been orthorectified and is ready for raster-to-vector conversion.	29
Figure 19. Individual (unedited) vector files from four adjacent photos.	30
Figure 20. Section of the vegetation database that has been edited, edge matched, and attributed.	31
Figure 21. Final map product for Map Sheet 5 (Barthell SW Quadrangle) of BISO.....	35
Figure 22. BISO Overview Map.	58
Figure 23. BISO Map Sheet 1 — Nevelsville Quadrangle.	59
Figure 24. BISO Map Sheet 2 — Bell Farm Quadrangle.	60
Figure 25. BISO Map Sheet 3 — Barthell Quadrangle.	61
Figure 26. BISO Map Sheet 4 — Sharp Place Quadrangle.	62
Figure 27. BISO Map Sheet 5 — Barthell SW Quadrangle.	63
Figure 28. BISO Map Sheet 6 — Oneida North Quadrangle.	64
Figure 29. BISO Map Sheet 7 — Stockton Quadrangle.	65
Figure 30. BISO Map Sheet 8 — Honey Creek Quadrangle.	66
Figure 31. BISO Map Sheet 9 — Oneida South Quadrangle.	67
Figure 32. BISO Map Sheet 10 — Burville Quadrangle.	68
Figure 33. BISO Map Sheet 11 — Rugby Quadrangle.....	69
Figure 34. Aerial photograph photo index map.	70

Tables

	Page
Table 1. Specifications of data sources available for map/database development of the Big South Fork NRRA vegetation databases.	11
Table 2. Community Key to Big South Fork Vegetation Map.	40
Table 3. Community Modifiers and Additional Categories.	43
Table 4. Big South Fork National River and Recreation Area Vegetation Codes.	44
Table 5. BISO Vegetation Statistics.	46
Table 6. BISO Buffer Vegetation Statistics.	47
Table 7. Photo Centers — Recorded on October 11, 2003.	47

Abstract

This report describes the vegetation mapping procedures employed by the Center for Remote Sensing and Mapping Science (CRMS), Department of Geography, University of Georgia, for the Big South Fork National River and Recreation Area (BISO) in the Appalachian Highlands Inventory and Monitoring Network (APHN) of the National Park Service under Cooperative Agreement No. H5028 01 0651, entitled, "Digital Vegetation Databases and Maps for National Park Service Units in the Appalachian Highlands and Cumberland/ Piedmont Networks." Big South Fork National River and Recreation Area (BISO) is located in the Cumberland Plateau of north central Tennessee and southern Kentucky. Encompassing a total area of 113,661 acres (45,997 hectares), BISO is a rugged area carved from sandstone and shale, and filled with river gorges, steep cliffs, and unique sandstone arches.

Using the National Vegetation Classification System (NVCS) developed by NatureServe, with additional classes and modifiers developed by CRMS, the vegetation communities for BISO were manually interpreted from 1:16,000 scale stereo color infrared aerial photographs acquired by Air Photographics, Inc. (Martinsburg, WV) in October 2003. Although the legislated area of BISO is 113,661 acres, the total area mapped was 122,368 ac (49,520 ha) and corresponds to the boundary file provided by the park. In addition, a 22,660 ac (9,170 ha) buffer area, extending 400 m outside of the park was mapped using a more general classification system meaning the total area mapped for BISO was 145,028 acres (58,793 ha).

Using a minimum mapping unit of 0.5 hectares (MMU = 0.5 ha), polygons representing areas of relatively uniform vegetation were delineated and annotated on clear plastic overlays registered to the aerial photographs. Polygons were labeled according to the dominant vegetation community. Where the polygons were not uniform, second and third vegetation classes were added. A number of modifier codes were employed to indicate important aspects of the polygon that could be interpreted from the photograph. The polygons on the overlays were then corrected using photogrammetric procedures and converted to vector format for use in creating a geographic information system (GIS) database for the park. High resolution color orthophotographs were created from the original aerial photographs for use in the GIS. Upon completion of the GIS database (including vegetation, orthophotos and updated roads and hydrology layers), both hardcopy and softcopy maps were produced for delivery.

Acknowledgments

This project was made possible through the support from the National Park Service Inventory and Monitoring Division. This study was sponsored by the U.S. Department of Interior, National Park Service, GRSM (Cooperative Agreement No. H5028 01 0651). The authors wish to express their appreciation for the devoted efforts of the staff at the Center for Remote Sensing and Mapping Science, The University of Georgia, the NPS Appalachian-Highlands Inventory and Monitoring Network and NatureServe.

Individuals from the above-mentioned organizations, as well as others who have participated in this project include: Robert Emmott, Nora Murdock, Patrick Flaherty, Bryan Wender, Marie Kerr, Mark Whited (photointerpreter), Amanda Humphries, Phyllis Jackson, Donna Johnson, Charles Jordan, Janna Masour, Carl Nordman, Mylo Pyne and Rickie White.

Introduction

As part of the USGS/BRD-NPS Vegetation Mapping Program, the Center for Remote Sensing and Mapping Science (CRMS), Department of Geography, University of Georgia, was requested to provide detailed vegetation maps of the parks in the Appalachian Highlands Inventory and Monitoring Network (APHN) of the National Park Service. This report describes the procedures and results of the vegetation mapping activities for Big South Fork National River and Recreation Area (BISO) undertaken by the CRMS under Cooperative Agreement No. H5028 01 0651, entitled, “Digital Vegetation Databases and Maps for National Park Service Units in the Appalachian Highlands and Cumberland/Piedmont Networks.” Big South Fork National River and Recreation Area (BISO) is located in the Cumberland Plateau of north central Tennessee and southern Kentucky.

Encompassing a total area of 113,661 acres (45,997 hectares), BISO is a rugged area carved from sandstone and shale, and filled with river gorges, steep cliffs, and unique sandstone arches.

Using the National Vegetation Classification System (NVCS) developed by NatureServe and adopted as a standard by the Federal Geographic Data Committee (FGDC 2008), with additional classes and modifiers defined by CRMS, vegetation associations and communities for BISO were interpreted using manual methods from 1:16,000-scale stereo color infrared aerial photographs acquired by Air Photographics, Inc. (Martinsburg, WV) in October 2003. For this project, vegetation associations, which include both understory and herb layers in their descriptions, were interpreted from the aerial photographs by inferring the community based on the overstory/canopy characteristics, supplemented with field work. Although the legislated area of BISO is 113,661 acres, the total area mapped was 122,368 ac (49,520 ha) and corresponds to the boundary file provided by the park. In addition, a 22,660 ac (9,273 ha) buffer area, extending 400 m outside of the park was mapped using a more general classification system. Consequently, the total area mapped for BISO, including the park and buffer, was 145,028 acres (58,793 ha).

Using a minimum mapping unit of 0.5 hectares (MMU = 0.5 ha), polygons representing areas of relatively uniform vegetation communities were delineated and annotated on clear plastic overlays registered to the aerial photographs.

Polygons were labeled with CEGLE codes according to the dominant vegetation community (Appendix A, Table 4). Where the polygons were not uniform, second and third vegetation classes were added. Further, a number of modifier codes were employed to indicate important aspects of the polygon that could be interpreted from the photograph (for example, burn condition).

The polygons on the plastic overlays were then scanned and corrected using photogrammetric procedures and converted to vector format for use in creating a geographic information system (GIS) database for the park. In addition, high resolution color orthophotographs were created from the original aerial photographs for use in the GIS. Upon completion of the GIS database (including vegetation, orthophotos and updated roads and hydrology layers), both hardcopy and softcopy maps were produced for delivery.

Metadata for the vegetation database includes a description of the vegetation classification system used for the park, summary statistics and documentation of the sources, procedures, and spatial accuracies of the data. At the time of this writing, the accuracy assessment of the vegetation mapping is underway but has not yet been completed for this park. Thus, those procedures and results will be provided in a separate report.

The Center for Remote Sensing and Mapping Science (CRMS), Department of Geography at The University of Georgia (www.crms.uga.edu), has been involved in vegetation mapping and database development in national parks of the southeastern United States for the past 10 years (Welch et al. 1995, 1999, 2002; Welch and Remillard 1996). As a remote sensing and mapping facility, the CRMS is unique in its combination of expertise in both technical and biological aspects of vegetation mapping projects. Scientists at the CRMS specialize in image processing, photogrammetry, GIS, air photo interpretation and field surveying, as well as botany, biology, and ecology. This allows a close link between the three major components of a vegetation mapping/database project: 1) photogrammetric rectification; 2) vegetation interpretation, classification, and field verification; and 3) GIS database construction.

In addition to in-house cross training of technical and biological skills, the CRMS has developed a strong working relationship with NatureServe, a non-profit conservation organization that developed the U.S. National Vegetation Classification System (NVCS) and is a primary partner in the USGS-NPS National Vegetation Mapping Program (<https://www.natureserve.org/>). Collaboration between the CRMS and the NatureServe-Durham, North Carolina Office has resulted in the development of a detailed classification system for southeastern park lands that maximizes the information on vegetation communities that can be gleaned from large-scale color infrared aerial photographs, while remaining compatible with the U.S. National Vegetation Classification System (Grossman et al. 1998a; Jackson et al. 2002).

Objectives

The objectives of this report are to:

1. describe the mapping procedures employed to map the vegetation communities of Big South Fork National River and Recreation Area (BISO);
2. demonstrate how digital photogrammetry, photointerpretation, GIS and Global Positioning Systems (GPS)-assisted field techniques were refined, adapted and integrated to permit the construction of geocoded vegetation databases from large-scale aerial photographs;
3. discuss the NVCS in general and its adaptation for use in parks in the Appalachian Highlands I&M Network; and
4. provide classification systems, summary statistics and vegetation maps for the park.

Digital data in the form of ArcGIS geodatabases, shapefiles, orthophotos and metadata are provided on the accompanying DVDs. Most of the techniques described below were first developed and refined during the mapping of Great Smoky Mountains National Park, which is considered to be one of the most difficult terrain areas to map in the United States (Jordan 2002; Madden et al. 2004).

Study Area

Big South Fork National River and Recreation Area (BISO) is located in the Cumberland Plateau of north central Tennessee and southern Kentucky.

Encompassing a total area of 113,661 acres (45,997 hectares), BISO is a rugged area carved from sandstone and shale, filled with river gorges, steep cliffs and unique sandstone arches. First settled in 1780, the region was heavily logged and mined throughout the early twentieth century and finally abandoned in the early 1960s. The Big South Fork of the Cumberland River was designated the first National River and Recreation Area in the United States in 1974 following a decision to preserve the region rather than to build a dam in an effort to spur economic development. As a result, this unique area with its deep gorges, old homesteads, rockshelters, arches and extensive archeological record was protected. In the succeeding years, the vegetation, which had been extensively damaged by mining and logging, has had a chance to return and the Big South Fork has become habitat for a number of federally listed rare and endangered species. The “river scour prairies”, which are found only in the areas of the Big South Fork and the Obed Rivers, are ranked as globally imperiled by The Nature Conservancy. These habitats occur on open, flood-scoured exposures of bedrock, cobble, and gravel along these large rivers in the Cumberland River watershed (Figure 1; NPS 2009).

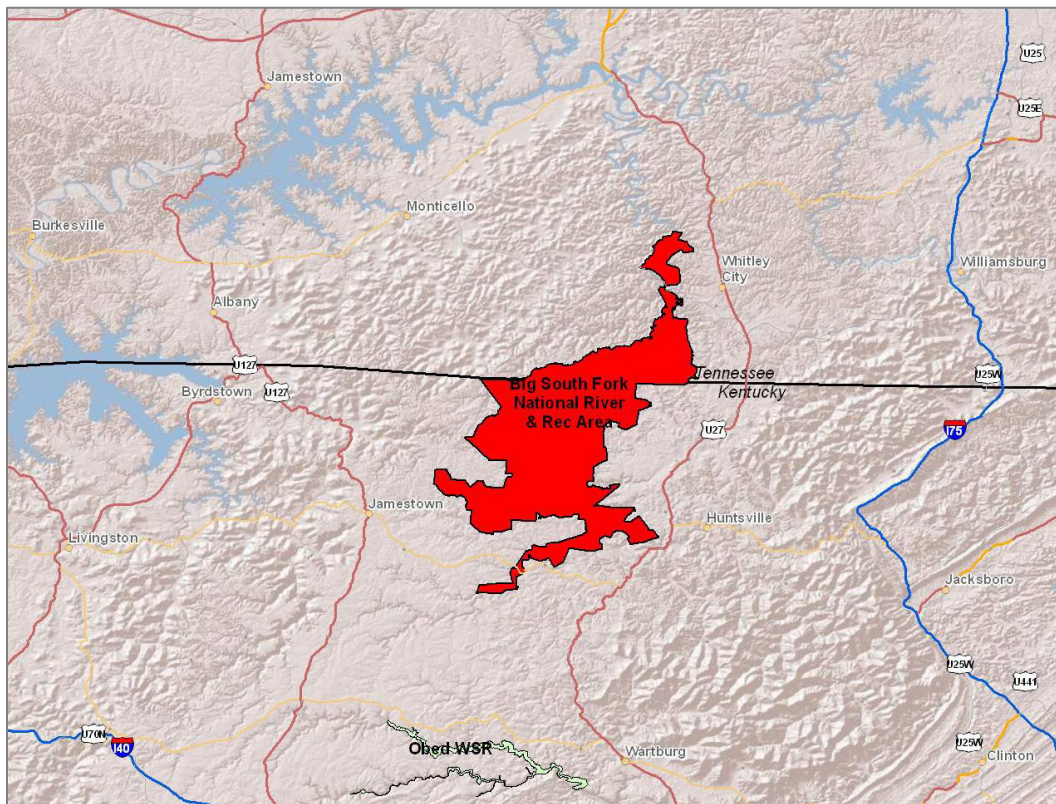


Figure 1. Big South Fork National River and Recreation Area is located on the Cumberland Plateau in north-central Tennessee and southern Kentucky.

Although the legislated area of BISO is 113,661 acres, the total area mapped was 122,368 ac (49,520 ha) and corresponds to the boundary file provided by the park. In addition, a 22,660 ac (9,273 ha) buffer area, extending 400 m outside of the park was mapped using a more general classification system. Consequently, the total area mapped for BISO, including the park and buffer, was 145,028 acres (58,761 ha) (Figure 2).

Requirements

The primary requirement for the project was to produce a vegetation database and associated maps in vector format that contained polygons for vegetation associations and communities plotted to within approximately ± 5 to 10 m of their true ground locations. To accomplish this, vegetation was mapped using color infrared aerial photographs of 1:16,000 scale in film transparency format recorded with a standard photogrammetric mapping camera ($f = 15$ cm) on October 11, 2003 by Air Photographics, Inc. (Martinsburg, WV) (Appendix B, Figure 34). The fall photos were acquired when the leaves were still on the trees (leaf-on) and displayed a color diversity that allowed the vegetation communities/species to be identified (Figure 3). Vegetation associations, which include both understory and herb layers in their descriptions, were interpreted from the aerial photographs by inferring the community based on the overstory/canopy composition, together with the topographic position, and other physical characteristics of the site. Relief displacements were a major consideration in the mountainous areas and required photogrammetric correction methods in order to ensure geometric accuracy (Jordan 2004). Using ground control obtained from USGS Digital Orthophoto Quarter-Quads (DOQQ) and the National Elevation Dataset (NED), polygons were plotted to within approximately ± 5 m of their true ground locations, thus meeting National Map Accuracy Standards for 1:15,000 scale maps and exceeding the requirements for 1:24,000 scale maps.

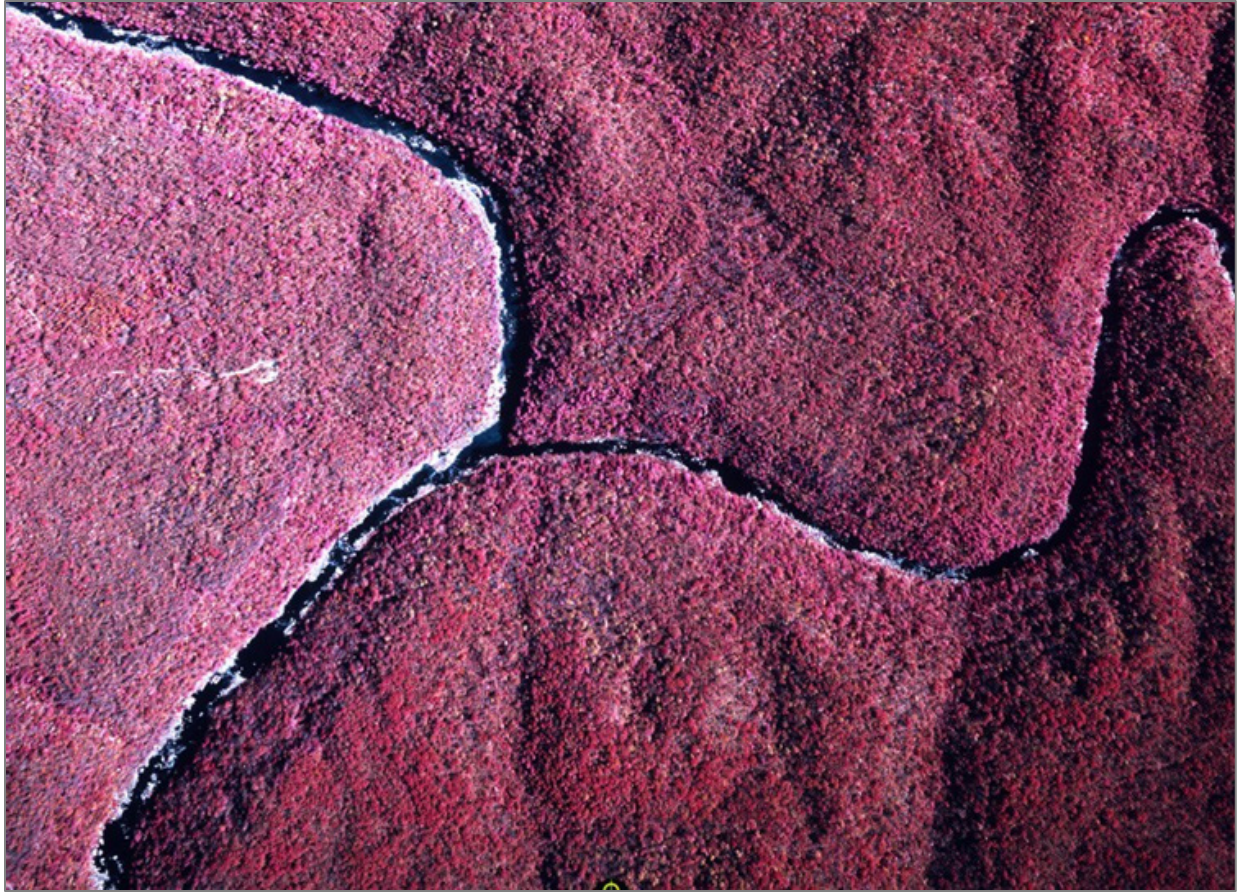


Figure 3. A portion of a 1:16,000 scale color infrared aerial photograph of the confluence of the Big South Fork (lower left) with its two major tributaries, New River (upper left) and Clear Fork (right), recorded on October 11, 2003 and used for photo interpretation of vegetation detail.

In general, the mapping tasks are divided into four major categories of operations:

1. Collection and integration of collateral datasets.
2. Photogrammetry, which includes the initial scanning and orthorectifying of the CIR photographs and subsequent rectification of the interpreted overlays.
3. Photointerpretation and ground truthing, which includes delineation and attribution of polygons representing vegetation classes on aerial photographs.
4. Geographic information systems (GIS), which includes converting the photointerpretation to vectors, editing and attributing the vegetation polygons and creating the final GIS database and hardcopy maps.

Final products include the following:

1. Overstory vegetation maps in digital format attributed according to the National Vegetation Classification System (NVCS).

2. Generalized vegetation classes for a buffer area extending 400 m outside of the park boundary.
3. Digital orthophotos created from the CIR aerial photographs.
4. Updated roads and hydrology line work within park boundaries.
5. Hard and softcopy maps of the final database.
6. Metadata in the National Park Service format for the vegetation map and orthophotos.

As most national parks are located in natural areas with typically dense forest cover, steep slopes, absence of ground control and high relief, the construction of a vegetation database accurate in both the spatial and thematic context necessitated a combination of softcopy photogrammetry, manual photo interpretation and GIS procedures organized in parallel as shown in Figure 4. These are discussed below.

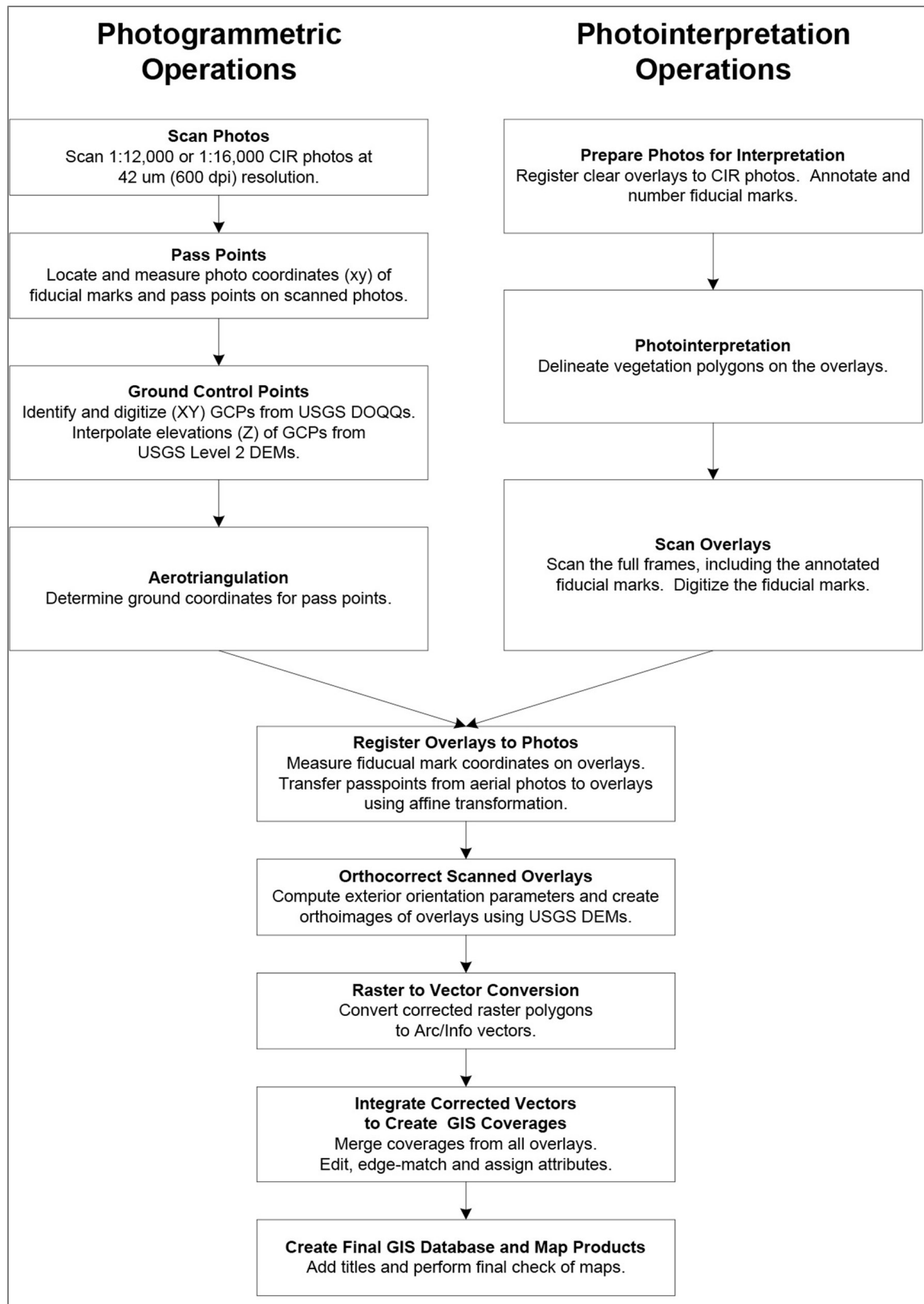


Figure 4. Generalized diagram showing photogrammetric, photointerpretation, and GIS operations used to map vegetation from aerial photographs by the CRMS. Photos of BISO were at 1:16,000 scale.

Collateral Datasets

A base GIS dataset was compiled for the park that consisted of a combination of publicly available data layers and those provided by the park resource managers (Table 1). Basic layers included existing roads and trails, hydrology, boundaries, digital raster graphics (DRGs), digital orthophoto quarter quads (DOQQs), digital elevation models (DEMs), and any available additional ancillary data layers, such as geology, soils, and historical vegetation maps. All data layers were cast on the Universal Transverse Mercator (UTM) coordinate system, North American Datum of 1983 (NAD83), in the UTM Zone 16. Roads, trails, and streams within the park boundaries were updated to correspond to the DOQQs wherever they were visible. These updated data layers are included in the geodatabase created for this project.

Table 1. Specifications of data sources available for map/database development of the Big South Fork NRR vegetation databases.

Data Source	Format and Type of Data	Flying Height (FH) and/or Scale	Resolution	Comments
Color Infrared (CIR) Air Photos October 11, 2003	23 × 23 cm Analog film transparencies	FH = 2400 m 1:16,000	~ 0.67 m	Fall leaf-on conditions are ideal for mapping overstory forest communities.
USGS Digital Raster Graphics Topographic Maps	Digital scanned topo maps	1:24,000	2.33 m	Last updated 1970s. A good base map but missing some more recent cultural features.
USGS DOQQs Pan (1993) and CIR (1999)	Digital Orthophotos	FH = 6000 m 1:40,000	1 m	USGS DOQQs have a planimetric accuracy of approximately ± 3 m RMSE. Winter photographs.
USGS Level 2 DEMs	Digital Elevation Models	1:24,000	30 m post spacing	USGS Level 2 DEMs have a vertical accuracy of approximately ± 3–5 m RMSE.
NPS best-available park boundaries	Digital vector data (shape files)	1:24,000	N/A	We used the most current boundary files available from the NPS at the time of map compilation.
USGS DLG Census TIGER Line Files National Hydrology Dataset (NHD)	Digital vector data (shape files) roads, trails, hydrology, political boundaries	1:24,000	N/A	We used the best vector datasets available. Usually provided by NPS or retrieved from the USGS Seamless database.

Photogrammetric Operations

The main objective of the photogrammetric procedure was to create a set of color infrared orthophotos from the same aerial photographs that were being used for the vegetation mapping. To accomplish this, we first had to densify the sparse ground control in the park by means of aerotriangulation, a photogrammetric operation whereby a relatively small number of ground control points (GCPs) are used to mathematically compute the ground coordinates of a much larger number of identified pass points (Jordan 2002). In this way, an adequate control network is generated for the orthophoto rectification process. These control points were also used to rectify the interpretation overlays.

Scanning

The CIR aerial photographs in transparency format were scanned at 600 dpi (42 μm) using an Epson Expression 10000XL flatbed scanner. This scanner is capable of scanning materials up to 11 $\times$ 17" in size at optical resolutions up to 1200 dpi and is equipped with a backlight attachment for scanning transparent materials. The 600 dpi scanning resolution was selected to balance the resolution requirements for the orthophotos with data storage and processing considerations. The photographs were laid on the scanning surface and, to reduce distortions, a heavy piece of clear glass was placed on top to ensure flatness of the film during scanning. Each photo was then scanned using Adobe Photoshop and saved as a 24-bit color TIFF file. During scanning, care was taken to scan the full frame of the photograph, including the corner fiducial marks and marginal data. File names for the scanned photographs were assigned according to the flight line and frame number. For example, photo 13 from flight line 2 was named 2-13.tif. Photos were stored on the CRMS data server. All photos from each flight line were scanned. For original photos of 1:16,000-scale, the resulting pixel size was approximately 0.5 m. After the photos were scanned, the original film transparencies were turned over to the photointerpreters while the photogrammetric operations continued using the digital data.

Ground Control and Pass Point Measurement

These digital photos were then displayed on the computer monitor and with the aid of the *R-WEL, Inc.* Desktop Mapping System (DMS) software package, the image (x,y) coordinates of pass points and GCPs were measured in the softcopy (computer, heads-up digitizing) environment. This was a painstaking and time-consuming task. Pass points were selected and measured on adjacent photographs. In some parks, there were enough cultural features so that features such as driveways, road intersections, parking lots, or sidewalks could be used as pass points. In other cases, it was necessary to use hay bales, bare spots in a field, creeks, rocks, or trees as pass points (Figure 5).

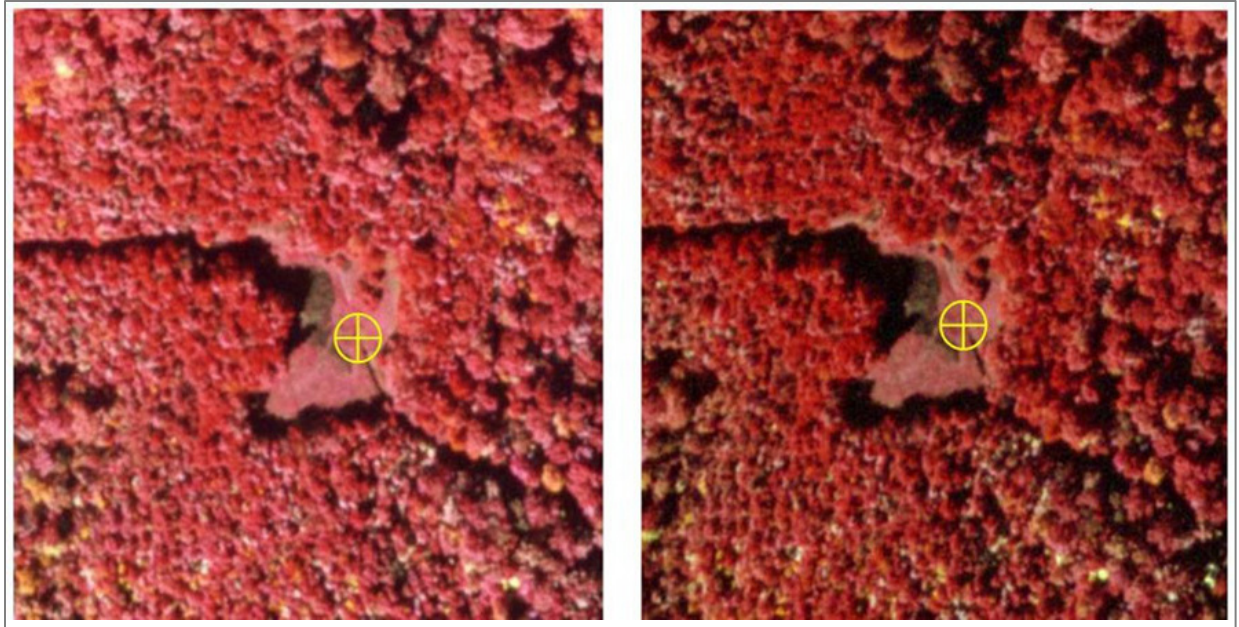


Figure 5. Well-defined natural and manmade features were used as pass points in overlapping images (yellow cross in circle symbols in the photos above). At least nine pass points per photo were identified with six being in the stereo overlap area between adjacent photos.

Ground control points were, for the most part, well-defined man-made and natural features (e.g., road intersections, parking lots, rock outcrops and forks in stream channels) identified on both the scanned color infrared transparencies and USGS Digital Orthophoto Quarter Quads (DOQQs) produced from 1:40,000-scale panchromatic or color infrared (CIR) aerial photographs recorded in 1993 or 1998. The Universal Transverse Mercator (UTM) grid coordinates (X,Y tied to the North American Datum of 1983 or NAD 83) of these GCPs were measured directly from the DOQQs (accurate to within ± 3 m). Elevations for the GCPs were derived using CRMS custom software to interpolate the Z-coordinates to within ± 3 to ± 5 m from USGS Level 2 Digital Elevation Models (DEMs) with 30-m post spacing (Figure 6). Thus, in this project, no ground survey work was required (or performed) to obtain the GCPs needed as a framework for the aerotriangulation process.

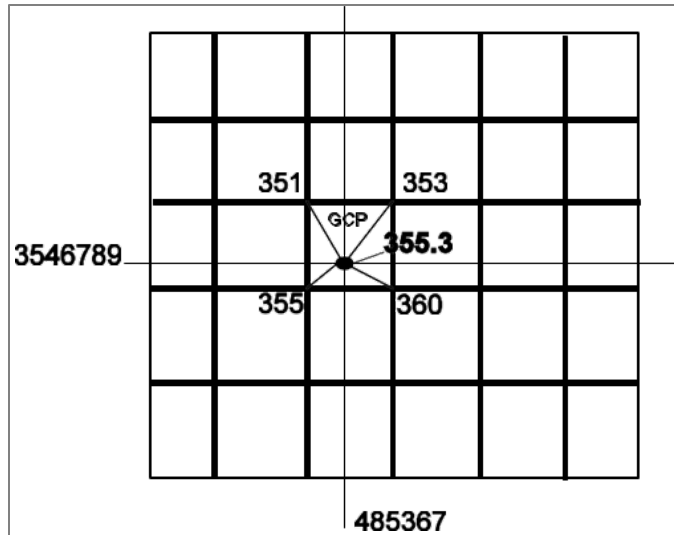


Figure 6. The elevations of ground control points (GCPs) were determined from the 30-m digital elevation model (DEM) using a bilinear interpolation algorithm.

Aerotriangulation

Analytical aerotriangulation was undertaken on a flight line by flight line basis and then all of the flight lines for the park were merged for the final run. The Aerosys software package, in conjunction with the DMS software, was employed for the aerotriangulation process. Output from the aerotriangulation was a set of X, Y and Z coordinates in the UTM coordinate system for the nine or more pass points identified by CRMS personnel on each photo. Typical root-mean-square error (RMSE) values for these coordinates averaged ± 5 m for the XY vectors and ± 6 m for elevations (Z).

Nine pass points per photo were measured and transferred to adjacent photos in the flight line. In addition, a number of ground control points were measured on the DOQQ and each photo (Figure 7). In the aerotriangulation process, the individual photos are joined numerically, related to the ground coordinate system using the GCPs and then the ground coordinates of the pass points are calculated. This dense network of GCPs can then be used to orient and orthorectify the CIR aerial photographs and to generate orthophotomosaics (Figure 8). After the orthophotomosaic is generated, the seamlines between adjacent photos are examined for misalignment. Terrain features that are well aligned between individual photographs indicate a good overall solution. The orthophotos and mosaics, in turn, are employed as a base reference layer in the editing and attributing operations required to build the vector database.

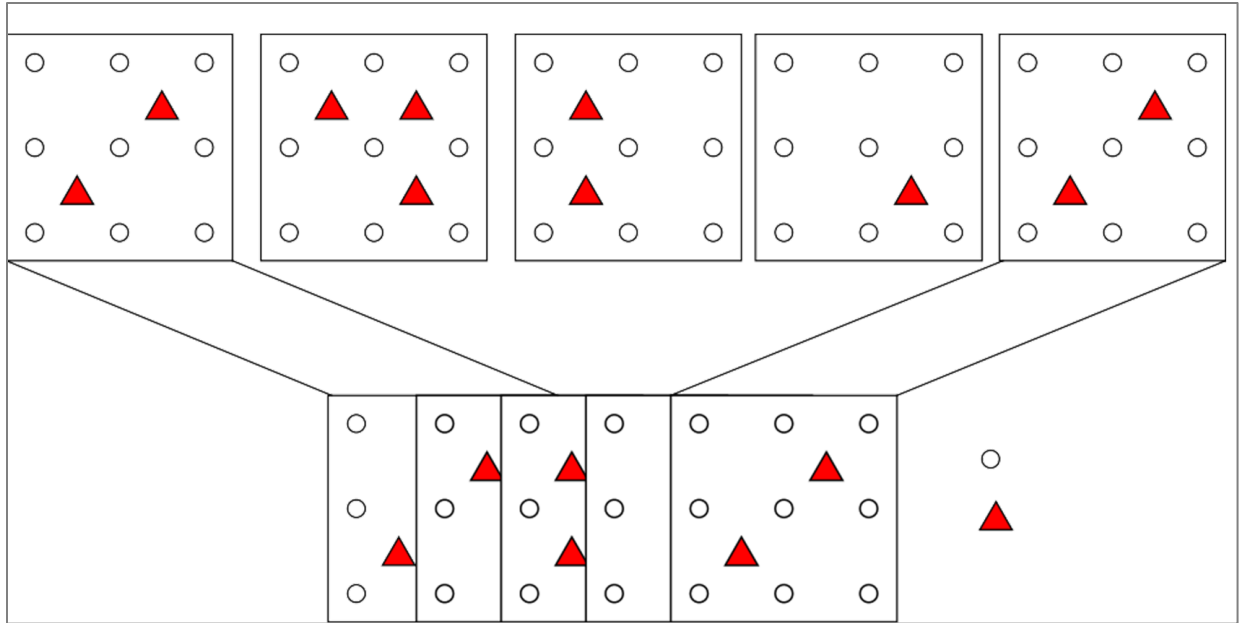


Figure 7. Nine pass points per photo and additional GCPs are measured and transferred to adjacent photos in the flight line.



Figure 8. A mosaic of orthorectified 1:16,000-scale photographs of BISO was created for quality assurance and checking and to provide an image backdrop for the GIS database. The ground pixel dimension is 0.75 m.

A critical use of the aerotriangulated GCPs is in the rectification of the vector overlays generated as part of the photointerpretation procedure described below. A well-aligned orthophoto mosaic provides the geometry and foundation necessary for the rectified vegetation linework of individual photographs to be edgematched correctly during the editing process.

Photointerpretation and Ground Truthing Operations

The steps of the photointerpretation process listed in Figure 4 proceeded in parallel with the photogrammetric operations. Overstory vegetation was interpreted from the 1:12,000-scale leaf-on color infrared aerial photographs in 9 × 9 inch film transparency format.

Although it might appear desirable to scan the color infrared transparencies at high resolution and undertake the vegetation classification as an on-screen interpretation and digitizing procedure, this has proved to be exceedingly time consuming, cumbersome, and expensive compared to more traditional approaches (Welch et al. 1995 and 1999; Rutchey and Vilchek 1999). More importantly, photointerpreters must view the vegetation and the terrain in stereo and in color within the context of a relatively large area of the landscape in order to identify the vegetation communities. This is most easily done using a stereoscope to view the analog air photos so that the vegetation patterns can be assessed in relation to the terrain. Recognizing the need to augment manual procedures with automated techniques, the steps described below integrate conventional photointerpretation procedures with digital processing technology in an attempt to streamline the database and map compilation process.

At the beginning of the mapping project, the photointerpreters, in conjunction with NatureServe and NPS plant specialists and resource managers, conducted field investigations to collect data on the vegetation communities and correlate signatures evident on the aerial photographs with ground observations.

Photointerpreters learned about management concerns and impacts to the vegetation communities and their distributions such as damage by exotic insects, fire, wind, excessive park use, etc. Information on land use history before and after the creation of the park, invasive plant species and ongoing park vegetation management practices also was critical to understanding past, present, and future vegetation conditions.

All of these factors must be taken into consideration during the photointerpretation process to ensure a meaningful vegetation classification system is used for the park and to accurately identify and portray the vegetation communities. At BISO, a total of four 2–4-day field trips were conducted, including an initial reconnaissance field visit to explore representative habitats, rare and important communities and managed, disturbed or invaded areas, as well as revisits to plots previously surveyed by NatureServe. Additional field visits were conducted during the interpretation process to verify initial interpretations, identify communities with unusual signatures and answer any questions.

Field sampling consisted of field data collection at numerous points along and off trails within the parks that were representative of both typical vegetation communities and unique or highly damaged areas (Figure 9). Points were selected to fall within areas identified on the aerial photographs as being unique or representative of typical areas. Additional points were selected as appropriate during the field survey whenever a new community was encountered. Methods and information collected resembled NatureServe's "Quick Plot" surveys. The percent cover of dominant overstory and

understory species was recorded for an area approximately 15 to 20 m around each point, along with any additional overstory/understory species identified and characteristics of the herb layer such as rich, sparse, dominant species, etc. Site conditions were noted by recording relative slope, aspect, and canopy openness. Notes on presence of exotics, evidence of past or present human influence (e.g., agriculture, grazing, logging, mowing, exotic vegetation removal, old homesites), damage by insects, wild hogs, blow down or fire also were recorded. Each point was geolocated by marking a waypoint with a Global Positioning System (GPS) handheld receiver such as a Garmin V or Garmin Geko. These units are Wide Area Augmentation System (WAAS)-enabled and typical horizontal positional accuracies were ± 3 to 5 m. The Estimated Positional Error (EPE) was noted for each field waypoint collected, especially when error approached or exceeded ± 10 m. The elevation of each field waypoint also was recorded, albeit vertical accuracy is generally more than two times lower than horizontal accuracy. As a back-up to the use of GPS for geolocation, field crews also carried paper field maps with the UTM grid coordinates, elevations, roads, and rivers superimposed on an image background, usually a USGS DOQQ (Figure 10). The maps were useful in planning the field route, marking notes, and augmenting the GPS digital display.



Figure 9. Conducting a field survey of the vegetation prior to beginning detailed photo interpretation. During this field survey, the vegetation communities are explored to correlate the community with its appearance on the aerial photograph.

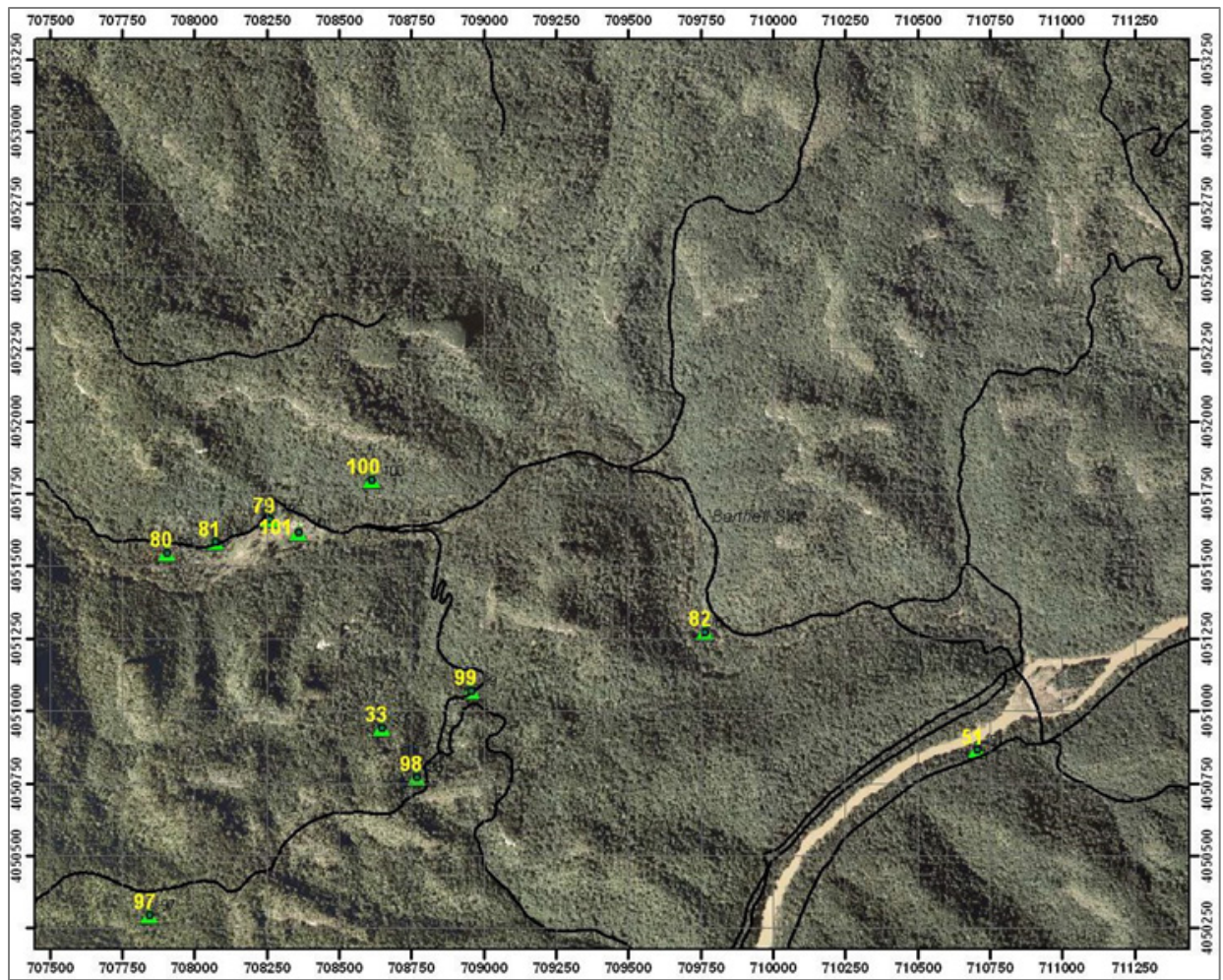


Figure 10. Field map for BISO used for field data collection with UTM grid, color orthophotos, roads, and rivers.

At each field point, the primary association type was determined based on NatureServe definitions of associations in the National Vegetation Classification System (NVCS) used in the USGS/NPS National Vegetation Mapping Program (i.e., NVCS Community Element Global (CEGL) code numbers) (Anderson et al. 1998b, Grossman et al. 1994 and 1998a). Since CRMS interpreters were usually accompanied by NatureServe botanists to assist with species identification and coordinate classification, interpretation, and accuracy assessment efforts, CRMS and NatureServe personnel would discuss and agree on the association designation before moving on. If the field point was located in a mixed area indicative of an ecotone or an area of successional recovery, both the dominant and secondary (and sometimes tertiary) associations also were determined. If there was no good match to an NVCS CEGL, careful notes were taken to allow later assignment of the appropriate CEGL or CRMS-created class (e.g., a managed, damaged, human influence or successional class). Spreadsheets containing these field points and observations are included in the Appendix of this document and in digital form on the accompanying DVD.

NatureServe developed a classification field key based on field plot surveys for BISO before the CRMS-NatureServe field work was conducted. During the subsequent field work, the key was jointly used, informally tested, and then modified, if necessary. Although this process tended to require considerable additional time that was outside of the scope of CRMS mapping tasks, its importance was recognized after NatureServe conducted some of the first accuracy assessments of CRMS vegetation databases. For the accuracy assessment to work properly, it is imperative that NVCS classes in the NatureServe field key match the classes used by CRMS for interpretation, that the definitions of the classes are not modified after the interpretation is completed and that CRMS and NatureServe botanists agree on the classes the keys “key-out” to.

During a full field day, the UTM coordinates and field data were typically collected at approximately 10 to 15 locations. Digital camera images were taken at most field points to document the vegetation and site conditions. Digital ground photos were tied to geographic locations with the aid of a Garmin hand-held GPS receiver. The GPS coordinates of each photo location were recorded along with the frame number, location, date, and time of each image as notes in the field notebook (Figure 11). These images were stored with the field notes and GPS locations to provide a pictorial record of field observations.



Figure 11. Example of a ground image showing overstory and understory vegetation along the Big South Fork River (NPS 2009).

A compilation of all field information was used by CRMS photointerpreters to connect the NVCS association-level classes identified in the field with photo signatures for vegetation patches identified on the color infrared aerial photographs. The locations of CRMS field points were transferred from the GPS units to ArcMap and superimposed on orthorectified images of BISO. Information from the field points on overstory, understory and herbaceous strata, environmental site conditions and any notes on human influence or disturbance were used to delineate areas of homogeneous vegetation communities into areas (i.e., vegetation polygons) and label (i.e., attribute) polygons with the appropriate NVCS association (i.e., CEGL).

The term *association* is defined by Grossman et al. (1998a) as a “plant community type of definite floristic composition, uniform habitat conditions and uniform physiognomy.” Vegetation classification studies by NatureServe were conducted prior to CRMS photointerpretation in most parks to create a list of typical NVCS associations and provide a comprehensive description of species found in one or several strata of vegetation: tree canopy, sub-canopy, tall shrub, short shrub, herbaceous, bryophytes, vine/liana, and epiphyte. The combination of vegetation present in all of these strata determines the community type and NVCS association CEGL. Additional information on global and local site conditions also is included in NatureServe park classification descriptions. This information was extremely helpful to CRMS interpreters and photointerpretation proceeded most smoothly when classification studies by NatureServe were completed prior to photointerpretation. Close cooperation between CRMS and NatureServe personnel in conducting field work and throughout the photointerpretation process was essential because in some cases CRMS interpreters found vegetation signatures on the aerial photographs that did not fit in the existing NVCS associations listed for the park. Since NatureServe plots are dispersed throughout the park and the intensity of field work that is required for each plot may limit the number of plots that can practically be surveyed, there were times when additional existing NVCS classes and even new vegetation classes to the NVCS classification system were identified by the photointerpreters. Careful consideration was given to these perceived “new” classes and in some cases additional NatureServe plots were established to document the vegetation in the field. It was more common that NatureServe definitions of NVCS associations would be modified to reflect the particular dominance or mix of species at particular sites.

It should also be noted that the term “*overstory vegetation*” refers to vegetation communities that are named and referenced by vegetation in their tallest stratum, plus abundant and/or indicator species in lower strata. Photointerpreters can see the tallest strata on color infrared photos and may or may not be able to see through this layer to shorter sub-canopy or understory layers. Sometimes a community can be determined solely by its location (e.g., along a ridge or on the south slope) and the uppermost stratum. In other cases, a lower stratum (or strata) must be seen because this stratum determines the community type. If supplemental air photos that were taken in leaf-off conditions were available at no cost for a park, such as USGS Digital Ortho Quarter Quads acquired in the winter months, then these photos were used to identify the type and density of the understory strata. This information, combined with species and abundances identified from field work, was used to separate NVCS classes with similar overstory components but different sub-canopy, understory, or herbaceous components. If it was not possible to determine the association-level class due to similar overstory

characteristics and lack of information on sub-canopy vegetation, then a more general class, perhaps at the alliance level, was assigned to the polygon.

The vegetation classification system used for BISO is provided in the Appendix of this report. The NVCS association-level classes listed as CEGL numbers and class names are fully described in separate documents produced by NatureServe and provided to the NPS on a park-by-park basis. Each of the parks in the Appalachian Highlands Network that were mapped by CRMS includes NVCS CEGLs with additional classes. Figure 12 and Figure 13 show the structure of this classification system for BISO. Modifiers to the NVCS classes, for example, can indicate variations of a particular NVCS class that are characteristic of the park being mapped and not well represented by the NVCS. The modifiers were added to the classification system to provide specific information about: 1) successional stages of vegetation communities; 2) damage conditions; 3) types of management practices (e.g., mowing or planting); and 4) land uses not covered by the NVCS, such as Human Influence, Residential, Commercial/Industrial, Agriculture and Roads (Figure 14).

This classification schema was employed in other NPS vegetation mapping projects such as Everglades National Park and Great Smoky Mountains National Park with considerable success (Madden et al. 1999; Jackson et al. 2002; Madden et al. 2004).

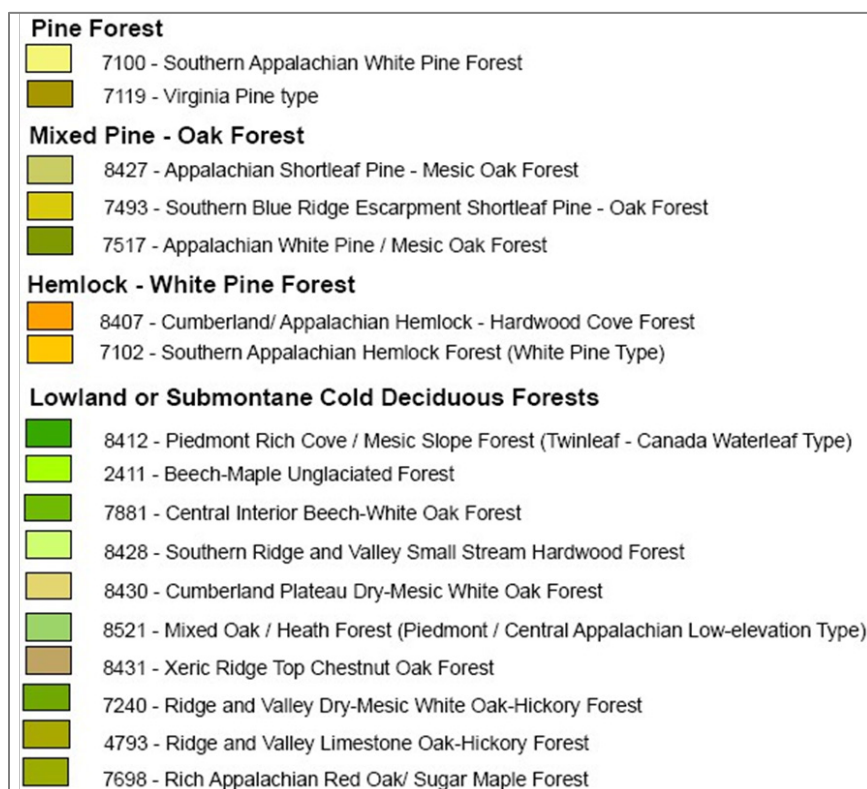


Figure 12. CRMS Vegetation Classification System for BISO that combines classes of the National Vegetation Classification System (NVCS), modified NVCS classes, land uses and special modifiers (Section 1 — Forest Classes).

Temporarily Flooded Forest	
	7143 - Montane Alluvial Forest (Small River Type)
	7312 - River Birch Levee Forest
	7340 - Sycamore - Sweetgum Swamp Forest
Successional Forest	
	7124 - Red Cedar Successional Forest
	7879 - Walnut Successional Forest
	7216 - Sweetgum Successional Forest
	7220 - Successional Tuliptree Forest (Circumneutral Type)
	7221 - Tuliptree Successional
	7330 - Successional Sweetgum Floodplain Forest
	2591 - Virginia Pine Successional Forest
	7944 - White Pine Successional Forest
Shrubland	
	4732 - Blackberry - Greebrier Successional Shrubland Thicket
	8470 - Cumberland Sandstone Glade Heath Shrubland
	8474 - Southeastern Smooth Alder Swamp

Figure 13. CRMS Vegetation Classification System for BISO that combines classes of the National Vegetation Classification System (NVCS), modified NVCS classes, land uses and special modifiers (Section 2 — Forest Classes (continued), Shrubland).

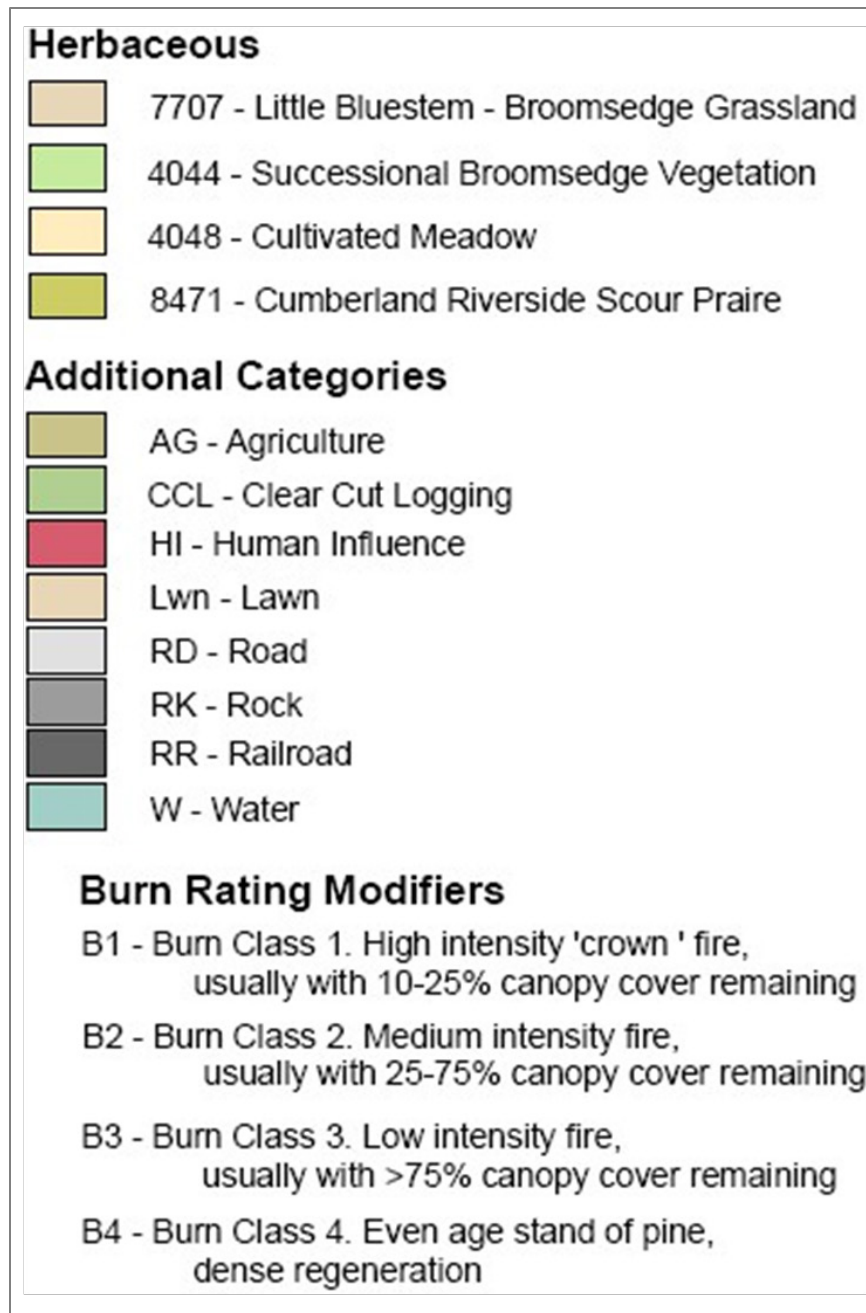


Figure 14. CRMS Vegetation Classification System for BISO that combines classes of the National Vegetation Classification System (NVCS), modified NVCS classes, land uses and special modifiers (Section 3 — Herbaceous, Additional Categories, Burn Rating Modifiers).

The NVCS is best suited to large parks that are relatively undisturbed and have remained so for long enough for vegetation communities to develop in accordance with the environmental and climatic conditions of the site. Areas that are regularly or extensively disturbed by logging, fire, wind damage, exotic insects, exotic vegetation, and human activities are not easily classified with the NVCS. For this reason, the CRMS augmented the NVCS classes developed for BISO by NatureServe to include

additional disturbed, managed, successional and modified classes, along with numerical and alpha modifiers to provide detailed information to users of the vegetation databases and maps (Figure 15).

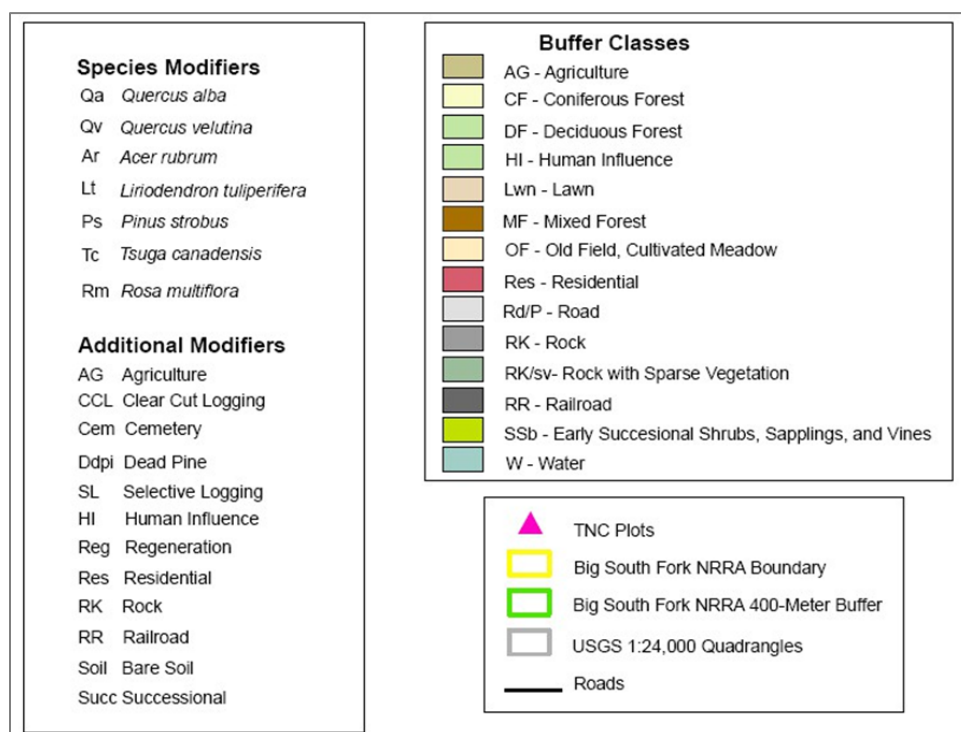


Figure 15. CRMS Vegetation Classification System for BISO that combines classes of the National Vegetation Classification System (NVCS), modified NVCS classes, land uses and special modifiers (Section 4 — Species and Additional Modifiers, Buffer Classes).

Once the overstory community classification systems were established for each park, the photointerpretation proceeded by taping transparent plastic overlays to the film transparencies, and transferring the photo numbers and fiducial marks to the overlays by means of a Rapidograph technical pen. The film transparencies, with plastic overlays, were then placed on a high intensity light table and the polygons corresponding to the vegetation classes were outlined on the overlay using the Rapidograph pen while viewing the photographs through a stereoscope. This is a simple, fast, inexpensive, and flexible method of creating a vegetation overlay that can be scanned to create a raster file.

In order to accommodate the complex vegetation patterns often found in National Park units and generally maintain a minimum mapping unit of 0.5 ha, a three-tiered scheme was developed for attributing vegetation polygons, similar to that developed for an earlier project in the Everglades of south Florida (Madden et al. 1999). The three-tiered scheme allowed photointerpreters to annotate each polygon in the database with a primary or dominant vegetation class accounting for more than 50 percent of the vegetation in the polygon. Where appropriate, secondary and tertiary vegetation classes were added to describe mixed-plant communities within the polygon. Secondary and tertiary

classes were especially useful for describing ecotones, and for polygons with a patchwork of communities below the minimum mapping unit size.

GIS Operations

Creating the Map Database

Following recommendations by Welch and Jordan (1996), the interpreted overlays were scanned using the Epson 10000 $\times$ 1 scanner at a resolution of 127 μ m (200 dpi) using Adobe Photoshop. All annotated point, line, polygon, and attribute information on the overlay was thus converted to raster format and saved as a black-and-white, 8-bit TIFF file (Figure 16). The parameters derived from the differential rectification of the scanned 1:16,000-scale photos (described above) were then applied to the scanned overlay files via registration with the transferred fiducial marks and the scanned overlays were orthorectified in the same manner as the original aerial photographs. Figure 17 illustrates the magnitude of polygon displacement in a mountainous area, as well as distortion in polygon shape and size, due to variable relief displacements across the photograph. The image on the left (Figure 17a) represents an uncorrected overlay with a superimposed 1-cm grid. After differential rectification to correct for relief displacement (Figure 17b), the grid appears to be distorted but, in fact, the lines on the overlay are in their correct planimetric locations as a result of the rectification process. Figure 18 shows the entire overlay after correction. The wavy edges of the overlay are an artifact of the process resulting from the corrections for relief displacements which are greatest along the edge of the photograph.

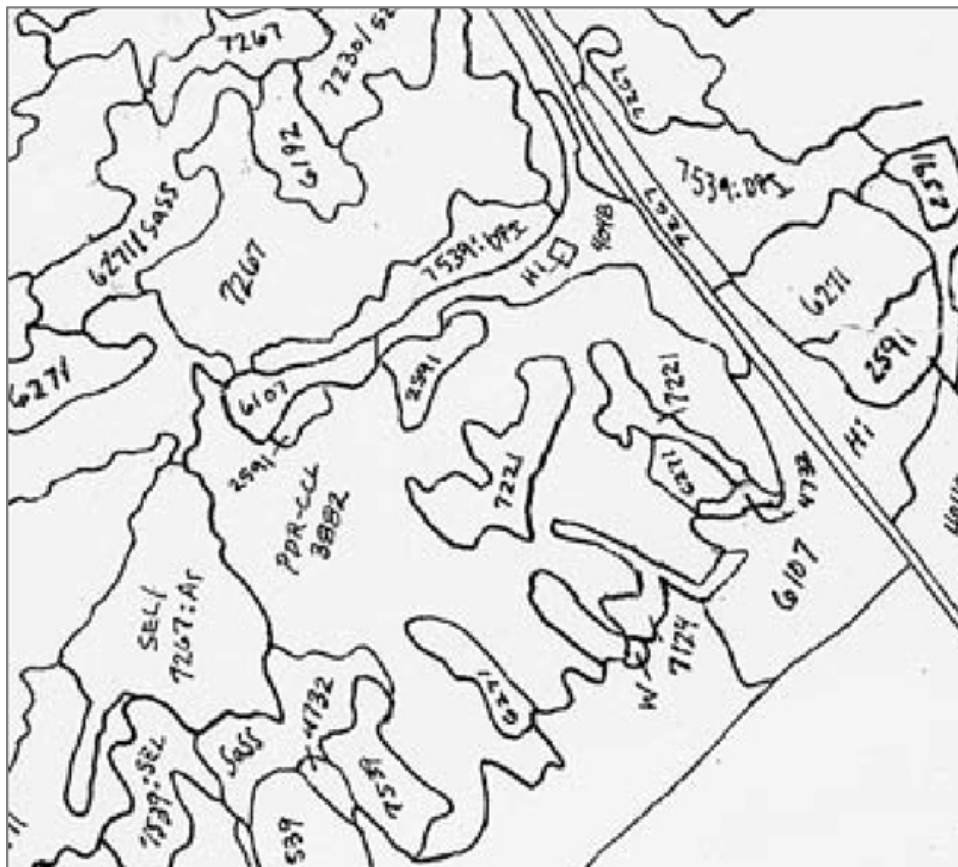


Figure 16. Sample scanned overlay showing vegetation polygons and CEGL code values.

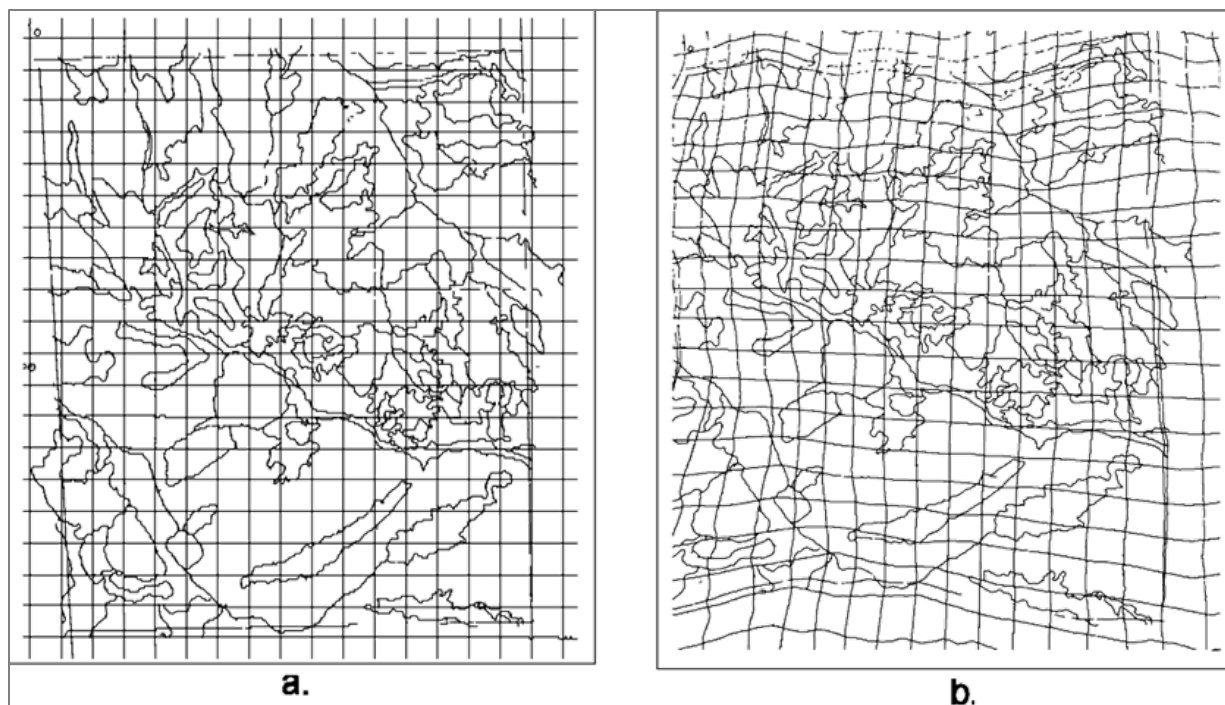


Figure 17. Photo overlay depicting vegetation polygons and a 1-cm grid before and after corrections for relief displacement. (a) Original photo overlay before corrections; (b) Overlay and grid after orthorectification showing the extreme corrections required to accommodate the large range of relief in the area.

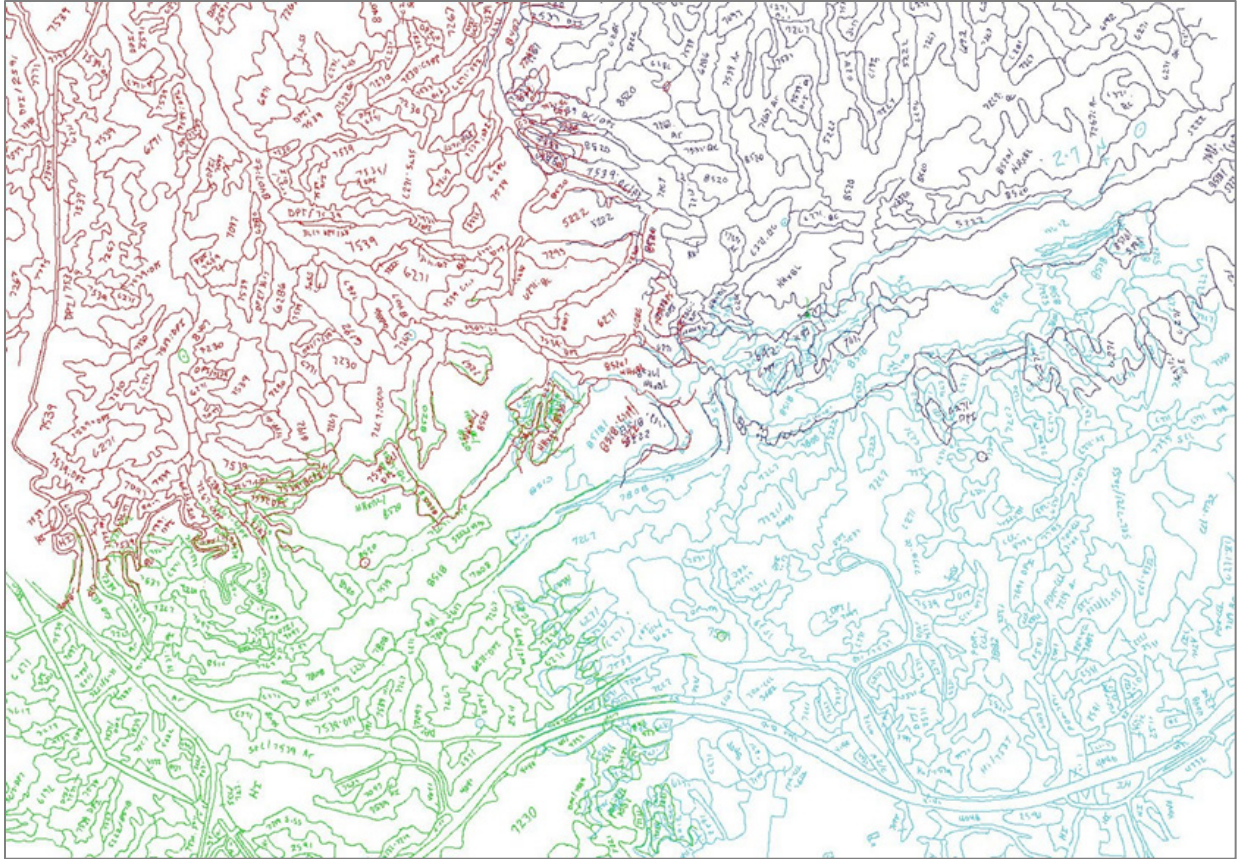


Figure 19. Individual (unedited) vector files from four adjacent photos.



Figure 20. Section of the vegetation database that has been edited, edge matched, and attributed.

Experience in the Great Smoky Mountains National Park has shown that a typical coverage for the area corresponding to a USGS 1:24,000-scale map can contain over 4,500 polygons that must be attributed with a dominant vegetation class, and possibly secondary and tertiary vegetation classes. Depending upon the complexity of the map, more than 700 man-hours can be required to produce a single quad-sized vegetation map from the 1:12,000-scale photos, including quality control checks of labels/line work within and between adjacent maps.

Although limited funds available for the project precluded a thorough check of thematic classification accuracy, maps were taken into the field as they were completed to assess the general agreement between map information and observations on the ground. A more thorough accuracy assessment of the vegetation will be performed by The Nature Conservancy as a separate project.

Quality Assurance/Quality Assessment

The final step before creating the actual map layouts was to perform quality assurance/quality assessment (QA/QC) inspections of the data. In this process, both the orthophotos and vegetation maps were checked to make sure that they fit the underlying DOQQs properly. In ArcMap, the DOQQ, orthophoto and vegetation layers were loaded and displayed in register with one another. The “Effects” toolbar provides a *swipe* feature which allows one layer to be rolled back to see the underlying layers. By rolling the topmost layer back and forth, any misregistration between layers

can be detected by visual inspection. This procedure was applied to both the orthophotos and the vegetation layer. Data mismatches of this sort resulted primarily from errors in aerotriangulation and ground control, orthophoto generation and edge matching operations. It was also possible that the photo interpreter did not delineate or attribute the feature correctly. When such a misregistration was found, the cause was determined, and the data were corrected.

Final Products

GIS Databases

Final products included a seamless park-wide GIS database in ArcGIS geodatabase and ArcView shapefile formats, of detailed overstory vegetation communities, along with vegetation statistics, large scale hardcopy maps and orthophoto images. More generalized vegetation/land use/land cover classes are provided for a 400-m buffer surrounding the park boundaries. Each map sheet contains a color-coded legend and brief description of all vegetation classes found in BISO. Applications of the park map/database products include: 1) vegetation assessment for general resource management tasks; 2) utilization of the overstory vegetation structure for classifying fuels and the associated risk of forest fire; 3) habitat assessment; and 4) provision of baseline data for future studies of vegetation or habitat change.

The vegetation databases provide a basis for park-wide resource management decisions. Basic information that is required by all managers includes a spatial inventory of existing vegetation communities and summary statistics indicating the total area covered by each community. These data can be quickly tallied in a GIS environment once the database has been developed. Comprehensive lists of all overstory and buffer vegetation classes as well as special modifiers are provided in this document (Appendix A, Tables 2 and 3) and also within the database and metadata. A summary of the respective areas of each dominant vegetation class within BISO is also provided (Appendix A, Tables 5 and 6).

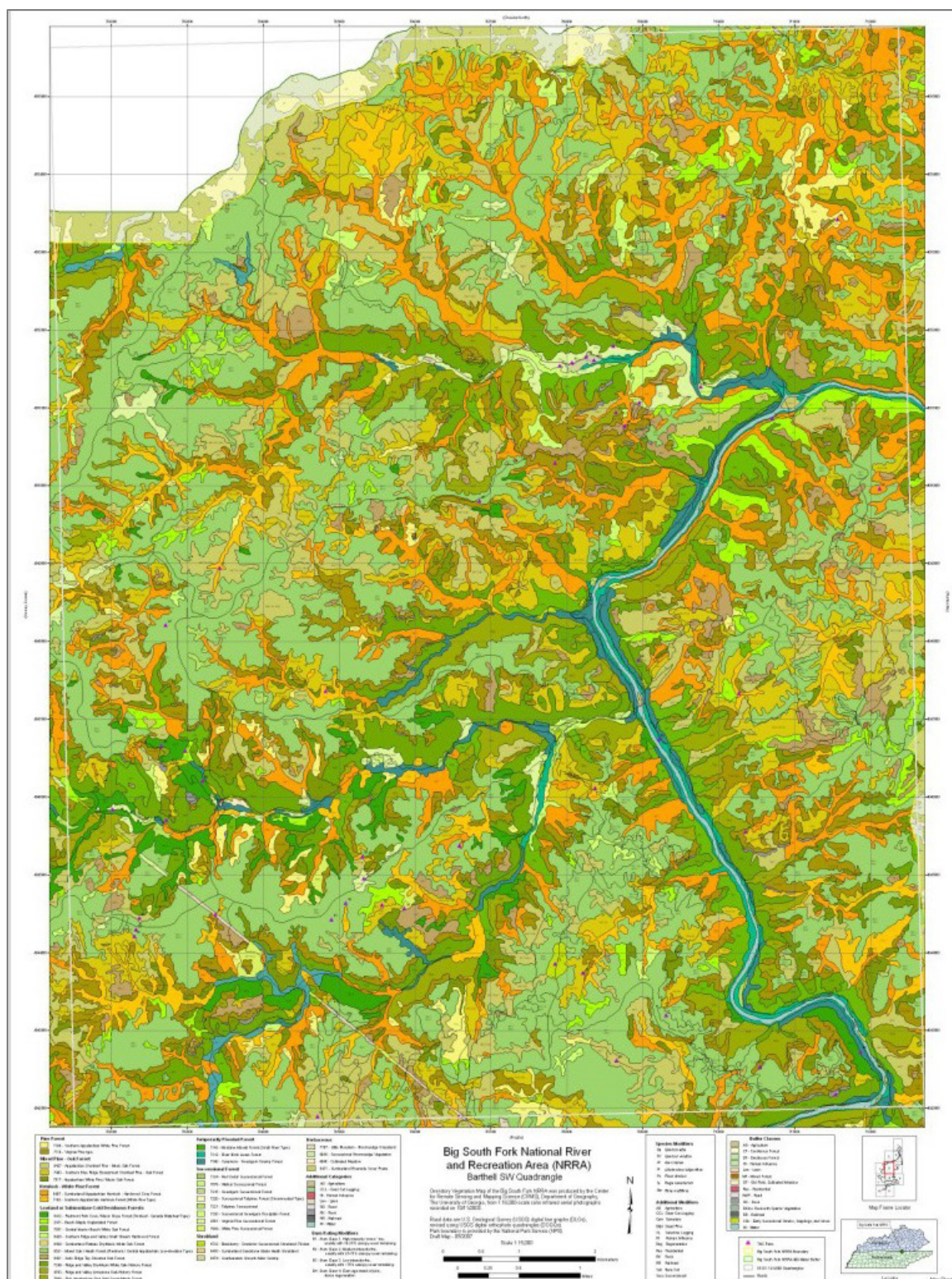
Detailed information at the association-level is often needed to address management problems that target individual species. For example, the overstory vegetation database can be queried to locate pure stands of Virginia Pine (*Pinus virginiana*) that might be susceptible to southern pine beetle infestation. The maps and databases also facilitate monitoring of important habitats such as Cumberland Riverside Scour Prairie (CEGL 8471) which contain rare and endangered plant species (NPS-APHN 2009). The BISO map and database documents 197 specific locations encompassing 262 ac (106 ha) of such habitat.

Other management questions may require a broader perspective. Given the vegetation diversity in the APHN parks, and BISO in particular, the vegetation maps will assist park managers with assessing general trends in vegetation patterns when posed with management questions on a park-wide level.

Map Products

Large scale final map products were created within ArcMap and designed to show both the orthophoto coverage and the vegetation maps. For the vegetation maps, colors were assigned, and the polygons labeled with the dominant vegetation and modifier and, where present, the second vegetation and modifier. Additional planimetric map data included roads, trails, hydrology, boundaries and a UTM coordinate grid. Legends were designed to provide full definitions of the vegetation and buffer classes and modifiers, as well as information about the park, map projection, data sources and authorship (Figure 21). All maps for BISO are projected to the Universal Transverse Mercator Coordinate System, North American Datum of 1983, Zone 16.

Large-format (3×4 ft) hardcopy maps were provided to the NPS as data were delivered during the course of the project, while softcopy versions in Adobe Acrobat (PDF) format were provided on DVDs. Final databases compiled and organized into ArcGIS Geodatabases and ArcView shapefiles, along with metadata complying with NPS and FGDC Standard version FGDC-STD-001-1998. These files also were included on the DVDs.



Summary and Conclusion

Vegetation in the Big South Fork National River and Recreation Area (BISO) in the Appalachian Highlands Inventory and Monitoring Network (APHN) was mapped by the Center for Remote Sensing and Mapping Science (CRMS), Department of Geography, University of Georgia under Cooperative Agreement No. H5028 01 0651, entitled, “Digital Vegetation Databases and Maps for National Park Service Units in the Appalachian Highlands and Cumberland/ Piedmont Networks.” Vegetation mapping of the park was accomplished using a set of procedures and methods originally developed by the CRMS for the Great Smoky Mountains National Park Vegetation Mapping Project (Madden et al. 2004). In this process, color infrared aerial photographs were acquired in the fall of 2003, timed to coincide with the peak color change of the trees. The mapping included three primary areas of activity: 1) photogrammetry; 2) photointerpretation and field survey; and 3) GIS database development and map creation.

Photogrammetric operations involved scanning the aerial photographs, the extension of ground control using analytical aerotriangulation and softcopy photogrammetric techniques, production of digital orthophotographs from the color infrared aerial photographs, and ortho-correction of the interpreted overlays in preparation for GIS database compilation. Photointerpretation was performed using manual methods on mylar overlays while viewing the aerial photographs in stereo on a light table. Although time-consuming, this method is superior to automated methods because it permits a much wider range of vegetation classes to be detected and delineated while drawing on the botanical and site-specific knowledge of the photo interpreter, in addition to collateral datasets such as NatureServe plot data, field survey notes from site visits, and maps showing topography and geology. Using a minimum mapping unit of 0.5 ha, polygons delineating areas of a single vegetation community were drawn on the mylar overlays and assigned a numeric CEG code corresponding to the appropriate National Vegetation Classification System (NVCS) class. Where a NVCS CEG code did not fit the interpretation, an alpha code or modifier (e.g., HI = Human Influence) was employed as a descriptor.

Upon completion of the photointerpretation, the overlays were scanned and orthorectified using the photogrammetric parameters determined previously and transferred fiducial marks as registration points. The lines drawn on the rectified overlays representing vegetation polygons were converted from raster to vector format using Feature Analyst Extension for ArcGIS and then edited, edge matched and, finally, assigned attributes to create the preliminary vegetation GIS database. After final checking by the photo interpreters, the database was finalized, and hardcopy and softcopy map products created for delivery to NPS.

For the Big South Fork National River and Recreation Area, a total of 55 unique vegetation classes were found over a total park and buffer area of 59,391 ha (146,758 acres), including 33 CEG, 8 non-CEG and 14 buffer classes. The average size of vegetation polygons inside the park is 5.3 ha (13 acres).

The NVCS system was found to work best in areas where the vegetation had been relatively undisturbed but did not truly account for successional or managed vegetation classes found during this project. For this reason, it was important for the photointerpreters and the NatureServe field botanists to work together to develop keys and to refine the classes to best fit the situation on the ground. This cooperation not only creates a better set of vegetation classes, but it also prevents serious errors from occurring in subsequent operations such as accuracy assessment surveys.

Literature Cited

- Federal Geographic Data Subcommittee (FGDC). 2008. National vegetation classification standard, Version 2. FGDC-STD-005-2008 (Version 2). 119 pp. Available from: http://www.fgdc.gov/standards/projects/FGDC-standards-projects/vegetation/NVCS_V2_FINAL_2008-02.pdf/. Accessed June 24, 2008.
- Grossman DH, Goodin KL, Li X, Faber-Langendoen D, and Anderson M. 1994. USGS-NPS vegetation mapping program: standardized national vegetation classification system, prepared for United States Department of Interior National Biological Service and National Park Service by The Nature Conservancy and Environmental Systems Research Institute, Arlington, Virginia and Redlands, California, respectively.
- Grossman DH, Faber-Langendoen D, Weakley AS, Anderson M, Bourgeron P, Crawford R, Goodin K, Landaal S, Metzler K, Patterson KD, Payne M, Reid M, Sneddon L. 1998a. International classification of ecological communities: terrestrial vegetation of the United States. Vol. I. The National Vegetation Classification System: Development, Status and Applications. The Nature Conservancy, Arlington, Virginia. 126 p.
- Grossman DH, Faber-Langendoen D, Weakley AS, Anderson M, Bourgeron P, Crawford R, Goodin K, Landaal S, Metzler K, Patterson KD, Pyne M. 1998b. International classification of ecological communities: terrestrial vegetation of the United States. Vol. II. The National Vegetation Classification System: List of Types. The Nature Conservancy, Arlington, Virginia. 502 p.
- Jackson P, White R, Madden M. 2002. Mapping vegetation classification system for Great Smoky Mountains National Park. Center for Remote Sensing and Mapping Science, Department of Geography, The University of Georgia. 7 p.
- Jordan TR. 2002. Softcopy photogrammetric techniques for mapping mountainous terrain: Great Smoky Mountains National Park [Doctoral dissertation]. University of Georgia. 193 p.
- Jordan TR. 2004. Control extension and orthorectification procedures for compiling vegetation databases of National Parks in the southeastern United States. In, M.O. Altan, Ed., International Archives of Photogrammetry and Remote Sensing, 35:657–662.
- Madden M, Jones D, Vilchek L. 1999. Photointerpretation key for the Everglades vegetation classification system. Photogrammetric Engineering and Remote Sensing. 65(2):171–177.
- Madden M, Welch R, Jordan T, Jackson P, Seavey R, Seavey J. 2004. Digital vegetation maps for the Great Smoky Mountains National Park, final report to the U.S. Dept. of Interior, National Park Service, Cooperative Agreement Number 1443-CA-5460-98-019. Center for Remote Sensing and Mapping Science, The University of Georgia, Athens, Georgia. 112 p.

- NPS-APHN. 2009. Cobble bar monitoring resource brief, Appalachian Highlands Network, National Park Service. Available from: [DataStore - Appalachian Highlands Network Resource Brief: Cobble Bar Monitoring \(nps.gov\)](#) Accessed August 1, 2009.
- NPS 2009. The Big South Fork National River and Recreation Area. Available from: <https://www.nps.gov/biso/index.htm>. Accessed October 10, 2009.
- Rutchev K, Vilchek L. 1999. Air photointerpretation and satellite imagery analysis techniques for mapping cattail coverage in a northern Everglades impoundment. *Photogrammetric Engineering and Remote Sensing*. 65(2):185–191.
- Welch RA, Jordan TR. 1996. Digital Orthophoto Production in a Desktop Environment. *GIM Magazine*. 10(7):26–27.
- Welch R, Madden M, Doren RF. 1999. Mapping the Everglades. *Photogrammetric Engineering and Remote Sensing*. 65(2):163–170.
- Welch R., Madden M, Jordan T. 2002. Photogrammetric and GIS techniques for the development of vegetation databases of mountainous areas: Great Smoky Mountains National Park, *ISPRS Journal of Photogrammetry and Remote Sensing*. 57(1–2):53–68.
- Welch R., Remillard M, Doren R.F. 1995. GIS database development for South Florida's National Parks and Preserves. *Photogrammetric Engineering and Remote Sensing*. 61(11):1371–1381.

Appendix A. Vegetation Classification and Statistics for Big South Fork National River and Recreation Area

Appendix A contains several tables including the community classification key (Table 2), community modifiers and additional categories used (Table 3), vegetation codes for each vegetation type (Table 4), statistics for the area and frequency of each vegetation type (Tables 5 and 6), and the locations data for each of the center points of photos used during the mapping (Table 7).

Table 2. Community Key to Big South Fork Vegetation Map.

Category	Community Type	NatureServe Element Code	Association
Upper Highlands	White Oak - Rock Chestnut Oak	CEGL008430 Cumberland Plateau Dry-Mesic White Oak Forest	<i>Quercus alba</i> - (<i>Quercus montana</i>) / (<i>Hydrangea quercifolia</i>) - <i>Viburnum acerifolium</i> / <i>Carex picta</i> Forest
	White Oak - Rock Chestnut Oak	CEGL008521 Mixed Oak / Heath Forest (Piedmont / Central Appalachian low-elevation Type)	<i>Quercus alba</i> - <i>Quercus (coccinea, velutina, montana)</i> / <i>Gaylussacia baccata</i> Forest
	White Oak - Rock Chestnut Oak	CEGL008431 Xeric Ridge top Chestnut Oak Forest	<i>Quercus prinus</i> – (<i>Quercus coccinea</i>) / <i>Carya pallida</i> / <i>Vaccinium arboreum</i> – <i>Vaccinium pallidum</i> Forest
	Pine Forests	CEGL007119 Virginia Pine type	<i>Pinus virginiana</i> - <i>Pinus (rigida, echinata)</i> - (<i>Quercus montana</i>) / <i>Vaccinium pallidum</i> Forest
	Pine Forests	CEGL007100 Southern Appalachian White Pine Forest	<i>Pinus strobus</i> / <i>Kalmia latifolia</i> - (<i>Vaccinium stamineum</i> , <i>Gaylussacia ursina</i>) Forest
	Mixed Forests of Pine – Oak	CEGL007493 Southern Blue Ridge Escarpment Shortleaf Pine - Oak Forest	<i>Pinus echinata</i> – <i>Quercus (prinus – falcata)</i> / <i>Oxydendrum arboreum</i> / <i>Vaccinium pallidum</i> Forest
	Mixed Forests of Pine – Oak	CEGL008427 Appalachian Shortleaf Pine - Mesic Oak Forest	<i>Pinus echinata</i> , <i>Quercus alba</i> / <i>Vaccinium pallidum</i> / <i>Hexastylis arifolia</i> – <i>Chimaphila maculate</i>
	Mixed Forests of Pine – Oak	CEGL007517 Appalachian White Pine – Mesic Oak Forest	<i>Pinus strobus</i> – <i>Quercus alba</i> type – (<i>Carya alba</i>) / <i>Gaylussacia ursine</i> (Mid – upper slopes, ridge tops, and disturbed bottoms) – <i>velutina</i> , <i>acerrub</i> , <i>lirio</i> , <i>falcata</i> , <i>rubra</i> , <i>prinus</i>
River Gorge and Low – Mid Slopes	White Oak	CEGL007240 Ridge and Valley Dry-Mesic White Oak-Hickory Forest	<i>Quercus alba</i> - <i>Quercus rubra</i> - <i>Carya ovata</i> / <i>Cercis canadensis</i> - <i>Juniperus virginiana</i> Forest
	White Oak	CEGL008428 Southern Ridge and Valley Small Stream Hardwood Forest	<i>Quercus alba</i> - (<i>Liriodendron tulipifera</i> , <i>Liquidambar styraciflua</i>) / <i>Calycanthus floridus</i> / <i>Athyrium filix-femina</i> Forest
	Beech / White Oak	CEGL007881 Central Interior Beech-White Oak Forest	<i>Fagus grandifolia</i> – <i>Quercus alba</i> / <i>Cornus florida</i> Forest

Table 2 (continued). Community Key to Big South Fork Vegetation Map.

Category	Community Type	NatureServe Element Code	Association
River Gorge and Low – Mid Slopes (continued)	Beech / White Oak	CEGL002411 Beech-Maple Unglaciaded Forest	<i>Fagus grandifolia</i> – <i>Acer saccharum</i> – <i>Liriodendron tulipifera</i> Unglaciaded Forest
	Rich Cove Hardwood Forests	CEGL007698 Rich Appalachian Red Oak/ Sugar Maple Forest	<i>Quercus rubra</i> - <i>Acer saccharum</i> - <i>Tilia americana</i> var. <i>heterophylla</i> - <i>Aesculus flava</i> - (<i>Cladrastis kentukea</i>) Forest
	Rich Cove Hardwood Forests	CEGL008412 Piedmont Rich Cove / Mesic Slope Forest (Twinleaf - Canada Waterleaf Type)	<i>Acer (nigra, saccharum)</i> – <i>Tilia americana</i> / <i>Asimina triloba</i> – <i>Jeffersonia diphylla</i> – <i>Hydrophyllum canadense</i>
	Rich Cove Hardwood Forests	CEGL004793 Ridge and Valley Limestone Oak-Hickory Forest	<i>Quercus muehlenbergii</i> – <i>Quercus alba</i> / <i>Cercis canadensis</i> / <i>Dirca palustris</i> Forest
	Forested Acid Slopes	CEGL008407 Cumberland/ Appalachian Hemlock - Hardwood Cove Forest	<i>Tsuga canadensis</i> - <i>Fagus grandifolia</i> – <i>Tilia americana heterophylla</i> / <i>Magnolia tripetala</i> Forest
	Forested Acid Slopes	CEGL007102 Southern Appalachian Hemlock Forest – (White Pine Type)	<i>Pinus strobus</i> – <i>Tsuga canadensis</i> / <i>Rhododendron maximum</i> – (<i>Leucothoe fontanesiana</i>) (low-mid slope) along river corridor
	Successional Forests	CEGL007221 Tulip tree Successional (Typic Type)	<i>Liriodendron tulipifera</i> Successional Forest
	Successional Forests	CEGL007220	Tulip tree Successional (Rich Type)
	Successional Forests	CEGL007216 Sweetgum Successional Forest	<i>Liquidambar styraciflua</i> forest
	Successional Forests	CEGL007944 White Pine Successional Forest	Successional <i>Pinus Strobus</i>
	Successional Forests	CEGL007879 Walnut Successional Forest	<i>Juglans nigra</i> Successional Forest
	Successional Forests	CEGL002591 Virginia Pine Successional Forest	<i>Pinus virginia</i> Successional Forest
	Successional Forests	CEGL007124 Red Cedar Successional Forest	<i>Juniperus virginia</i> Successional Forest
	Forested Wetlands – River Corridor	CEGL007312 River Birch Levee Forest	<i>Betula nigra</i> – <i>Platanus occidentalis</i> / <i>Alnus serrulata</i> / <i>Boehmeria cylindrica</i> Forest
	Forested Wetlands – River Corridor	CEGL007443 Cumberland Forested Acid Seep	<i>Acer rubrum</i> var. <i>trilobum</i> – <i>Nyssa sylvatica</i> / <i>Osmunda cinnamomea</i> – <i>Chasmanthium laxum</i> – <i>Carex intumescens</i> / <i>Sphagnum lescurii</i> Forest

Table 2 (continued). Community Key to Big South Fork Vegetation Map.

Category	Community Type	NatureServe Element Code	Association
River Gorge and Low – Mid Slopes (continued)	Forested Wetlands – River Corridor	CEGL007330 Successional Sweetgum Floodplain Forest	<i>Liquidambar styraciflua</i> (<i>Liriodendron tulipifera</i>) Temporarily Flooded Forest
	Forested Wetlands – River Corridor	CEGL007740 Sycamore – Sweetgum Floodplain Forest	<i>Platanus occidentalis</i> - <i>Liquidambar styraciflua</i> / <i>Carpinus caroliniana</i> - <i>Asimina triloba</i> Floodplain Forest
	Forested Wetlands – River Corridor	CEGL007701 Southeastern Interior Small Floodplain Forest (Rich Type)	<i>Platanus occidentalis</i> – (<i>Liquidambar styraciflua</i> , <i>Acer rubrum</i>) / <i>Carpinus caroliniana</i> / <i>Onoclea sensibilis</i> Forest
	Forested Wetlands – River Corridor	CEGL007143 Montane Alluvial Forest (Small River Type)	<i>Tsuga canadensis</i> - <i>Pinus strobus</i> Temporarily Flooded Forest
	Forested Wetlands – River Corridor	CEGL003737 Cumberland Open Acidic Seep Woodland	<i>Acer rubrum</i> var. <i>trilobum</i> / <i>Alnus serrulata</i> / <i>Calamagrostis coarctata</i> Seep Woodland
	Streamside Bog	CEGL007771 Cumberland Streamside Bog	<i>Carex gynandra</i> - <i>Scirpus cyperinus</i> - <i>Eriophorum virginicum</i> - <i>Osmunda cinnamomea</i> Herbaceous Seep
	Shrublands	CEGL008470 Cumberland Sandstone Glade Heath Shrubland	<i>Kalmia latifolia</i> - <i>Gaylussacia (baccata, brachycera)</i> Cumberland Shrubland
	Shrublands	CEGL004732 Rubus shrubland	<i>Rubus (argutus, trivialis)</i> - <i>Smilax (glauca, rotundifolia)</i> Ruderal Shrubland
	Shrublands	CEGL008474 Southeastern Smooth Alder Swamp	<i>Alnus serrulata</i> Southeastern Shrub Swamp
	Shrublands	CEGL003895 Rocky Bar & Shore (Alder - Yellowroot Type)	<i>Alnus serrulata</i> - <i>Xanthorhiza simplicissima</i> Wet Shrubland
Herbaceous Vegetation	Old Field	CEGL004048 Cultivated meadow	<i>Schedonorus (arundinaceus, pratensis)</i> Ruderal Grassland
	Old Field	CEGL007707 Little Bluestem - Broomsedge Grassland	<i>Schizachyrium Scoparium</i> - <i>Andropogon (gyrans, ternarius, virginicus)</i> Herbaceous Vegetation
	River Gorge/ Bog	CEGL008471 Cumberland River Scour Prairie	(<i>Salix caroliniana</i> – <i>Rhododendron arborescens</i>) – <i>Andropogon gerardii</i> – <i>Baptisia australis</i> – (<i>Solidago simplex</i> var. <i>randii</i>) Herbaceous Vegetation
	Cliffs/ Rock Outcrops	CEGL004061 Cumberland Plateau Clifftop Sandstone Barren	<i>Schizachyrium Scoparium</i> – <i>Danthonia sericea</i> – <i>Liatris microcephala</i> – (<i>Eurybia surculosa</i>) Wooded Herbaceous

Table 2 (continued). Community Key to Big South Fork Vegetation Map.

Category	Community Type	NatureServe Element Code	Association
Herbaceous Vegetation (continued)	Cliffs/ Rock Outcrops	CEGL004301 Cumberland Plateau Rockhouse Herbaceous Vegetation	<i>Heuchera parviflora</i> var. <i>parviflora</i> – <i>Trichomanes boschianum</i> – <i>Thalictrum mirabile</i> – (<i>Ageratina luciae-brauniae</i> , <i>Solidago albopilosa</i>) Herbaceous Vegetation
	Cliffs/ Rock Outcrops	CEGLI008432 Cumberland Plateau Wet Sandstone Cliff	<i>Osmunda cinnamomea</i> - <i>Rhynchospora capitellata</i> - <i>Thalictrum mirabile</i> Cumberland Seepage Cliff Vegetation
	Sparse Vegetation	CEGL004392 Cumberland Plateau Sandstone Cliff (Dry Type)	<i>Asplenium montanum</i> – <i>Heuchera parviflora</i> – <i>Silene rotundifolia</i> Sparse Vegetation

Table 3. Community Modifiers and Additional Categories.

Category	Modifier Abbreviation	Description	Additional Information
Community Modifier	REG	Regeneration of a specific community	It is usually associated with Fire disturbance. This typically occurs as later stages of 4732 with some resemblance of the original community.
	Suc	Successional Vegetation	{To be incorporated into Regeneration. REG replaces SUC}
	BRN	Burned at some time in the past.	Canopy grey/colorless usually over a large area with occasional large trees.
	Dpi	Dead Pines	–
	SEL	Selectively Logged	–
	CCL	Clear Cut Logging	–
	AGI	Agriculture	–
	HI	Human Influence	–
	W	Water	–
	RD	Roads	–
	RK	Rock Outcrops	–
Species Modifier	Ar	Red Maple (<i>Acer rubrum</i>)	–
	Lt	Tulip Poplar (<i>Liriodendron tulipifera</i>)	–
	Mr	Multiflora Rose (<i>Rosa multiflora</i>)	–
	Tc	Eastern Hemlock (<i>Tsuga canadensis</i>)	–

Table 3 (continued). Community Modifiers and Additional Categories.

Category	Modifier Abbreviation	Description	Additional Information
Burn Rating	1	High intensity Fire - (Charred-Crown Fire)	All shrubs, small trees consumed. All canopy trees consumed except for a few scattered living large trees with < 10% coverage remaining. Usually with > 75% bare soil exposed.
	2	Medium intensity Fire	The canopy has few large healthy trees with < 10% remaining. Large canopy trees are scattered and widely spaced apart. Subcanopy is partially enclosed generally with small crowns. There may also contain standing dead trees among the canopy and subcanopy. The overall signature is grey with speckled red/orange/pink usually in draws.
	3	Low intensity Fire / Time Frame - 5 years old	(a) The canopy has 25–50% of intact Forest structure remaining. Canopy trees are clustered across the landscape. The subcanopy is enclosed with moderate coverage of small crowned trees. Subcanopy trees shows signs of fire related stress. (b) If the subcanopy is dominated with red maple, { then leaves have fallen or brown/ dead when photo was taken} this signifies that the forest may not have been burned, but logged with last 20 years. {Lirio. does not seem to be a pioneer species across the highlands.}
	4	Dense Pine Regeneration	High intensity fire with a > 75% removal of the canopy and subcanopy. The result is a complete canopy removal allowing for dense pine regeneration.

Table 4. Big South Fork National River and Recreation Area Vegetation Codes.

Veg Code	Description
2411	Beech-Maple Unglaciaded Forest
2591	Virginia Pine Successional Forest
3895	Rocky Bar & Shore (Alder - Yellowroot Type)
4044	Successional Broomsedge Vegetation
4048	Cultivated meadow
4061	Cumberland Plateau Clifftop Sandstone Barren
4301	Cumberland Plateau Rockhouse Herbaceous Vegetation
4392	Cumberland Plateau Sandstone Cliff (Dry Type)
4732	Rubus shrubland
4793	Ridge and Valley Limestone Oak-Hickory Forest
7100	Southern Appalachian White Pine Forest
7102	Southern Appalachian Hemlock Forest (White Pine Type)
7119	Virginia Pine type
7124	Red Cedar Successional Forest

Table 4 (continued). Big South Fork National River and Recreation Area Vegetation Codes.

Veg Code	Description
7143	Montane Alluvial Forest (Small River Type)
7216	Sweetgum Successional Forest (Typic Type)
7220	Successional Tuliptree Forest (Rich Type)
7221	Tulip tree Successional
7240	Ridge and Valley Dry-Mesic White Oak-Hickory Forest
7312	River Birch Levee Forest
7330	Successional Sweetgum Floodplain Forest
7340	Sycamore - Sweetgum Swamp Forest
7493	Southern Blue Ridge Escarpment Shortleaf Pine - Oak Forest
7517	Appalachian White Pine / Mesic Oak Forest
7698	Rich Appalachian Red Oak/ Sugar Maple Forest
7701	Southeastern Interior Small Floodplain Forest (Rich Type)
7707	Little Bluestem - Broomsedge Grassland
7771	Cumberland Streamside Bog
7879	Walnut Successional Forest
7881	Central Interior Beech-White Oak Forest
7944	White Pine Successional Forest
8407	Cumberland/ Appalachian Hemlock - Hardwood Cove Forest
8412	Piedmont Rich Cove / Mesic Slope Forest (Twinleaf – Canada Waterleaf Type)
8427	Appalachian Shortleaf Pine - Mesic Oak Forest
8428	Southern Ridge and Valley Small Stream Hardwood Forest
8430	Cumberland Plateau Dry-Mesic White Oak Forest
8431	Xeric Ridge top Chestnut Oak Forest
8432	Cumberland Plateau Wet Sandstone Cliff
8470	Cumberland Sandstone Glade Heath Shrubland
8471	Cumberland River Scour Prairie
8474	Southeastern Smooth Alder Swamp
8521	Mixed Oak / Heath Forest (Piedmont / Central Appalachian low-elevation Type)
AG	Agriculture
CCL	Clear Cut Logging
HI	Human Influence
Lwn	Lawn
RD	Road
Res	Residential
RK	Rock
RR	Railroad
W	Water

Table 5. BISO Vegetation Statistics.

DomVeg	FREQUENCY	Shape_Area (m²)	Area_ha	Area_ac
2411	238	8067664	807	1993
2591	228	7364299	736	1819
4048	82	713927	71	176
4732	155	2990894	299	739
4793	24	696979	70	172
7100	204	5269591	527	1302
7102	219	1.4E+07	1371	3388
7119	1675	4.7E+07	4684	11570
7124	28	387524	39	96
7143	44	1930162	193	477
7216	3	23437	2	6
7220	5	95658	10	24
7221	102	2509527	251	620
7240	320	2.9E+07	2887	7131
7312	55	9784509	978	2417
7330	5	214089	21	53
7340	78	3867278	387	955
7493	1240	5.8E+07	5786	14291
7517	422	1.3E+07	1253	3094
7698	245	1.9E+07	1895	4680
7707	74	2433640	243	601
7879	7	63319	6	16
7881	189	1E+07	1008	2489
7944	61	1207589	121	298
8407	625	5.3E+07	5276	13033
8412	86	5208007	521	1286
8427	808	5.6E+07	5594	13817
8428	178	6934758	693	1713
8431	530	1.5E+07	1455	3594
8470	34	301077	30	74
8471	197	1059041	106	262
8474	2	53916	5	13
8521	941	1.2E+08	12074	29823
AG	13	408156	41	101
HI	71	303538	30	75
Lwn	9	94052	9	23
RD	11	336108	34	83

Table 5 (continued). BISO Vegetation Statistics.

DomVeg	FREQUENCY	Shape_Area (m²)	Area_ha	Area_ac
RK	262	755189	76	187
RR	1	1294	0	0
Res	25	358942	36	89
W	15	5945104	595	1468
TOTAL	9511	5E+08	50221	124045

Table 6. BISO Buffer Vegetation Statistics.

buffer_class	FREQUENCY	Shape_Area (m²)	Area_ha	Area_ac
AG	21	811081	81	200
CF	533	13507542	1351	3336
DF	655	37324180	3732	9219
HI	142	1337913	134	330
Lwn	3	94204	9	23
MF	565	29401689	2940	7262
OF	163	4478291	448	1106
RD/P	17	131835	13	33
RK	19	60909	6	15
RK/sv	3	11047	1	3
RR	1	64972	6	16
Res	66	519362	52	128
SSb	143	3650500	365	902
W	54	310186	31	77
TOTAL	2385	91703710	9170	22651

Table 7. Photo Centers — Recorded on October 11, 2003.

frame	lat	long	UTM X	UTM Y
2	36.4189	-84.841	693565	4032579
3	36.4318	-84.841	693520	4034009
4	36.4447	-84.841	693469	4035437
5	36.4575	-84.841	693479	4036856
6	36.4702	-84.84	693500	4038272
7	36.483	-84.84	693536	4039688
8	36.4958	-84.839	693565	4041115
9	36.5085	-84.839	693557	4042529
10	36.5213	-84.839	693497	4043941

Table 7 (continued). Photo Centers — Recorded on October 11, 2003.

frame	lat	long	UTM X	UTM Y
11	36.5712	-84.807	696196	4049538
12	36.5583	-84.808	696196	4048112
13	36.5457	-84.808	696216	4046708
14	36.5328	-84.808	696250	4045286
15	36.5202	-84.808	696260	4043882
16	36.5074	-84.809	696230	4042457
17	36.4946	-84.81	696182	4041044
18	36.4819	-84.81	696164	4039630
19	36.4691	-84.81	696198	4038207
20	36.4563	-84.81	696233	4036786
21	36.4435	-84.811	696213	4035372
22	36.4305	-84.812	696180	4033924
23	36.4176	-84.812	696171	4032498
24	36.4045	-84.812	696190	4031044
25	36.3915	-84.812	696226	4029598
26	36.3787	-84.813	696212	4028170
27	36.2947	-84.788	698640	4018905
28	36.3078	-84.787	698684	4020362
29	36.3209	-84.787	698697	4021819
30	36.334	-84.786	698683	4023268
31	36.3469	-84.786	698697	4024707
32	36.36	-84.786	698682	4026159
33	36.3731	-84.785	698675	4027612
34	36.3861	-84.784	698715	4029058
35	36.3991	-84.784	698770	4030501
36	36.4122	-84.783	698748	4031951
37	36.4252	-84.783	698709	4033392
38	36.4381	-84.783	698703	4034821
39	36.451	-84.783	698710	4036262
40	36.4639	-84.782	698748	4037692
41	36.4768	-84.781	698769	4039128
42	36.4897	-84.782	698716	4040553
43	36.5025	-84.781	698706	4041975
44	36.5153	-84.781	698728	4043400
45	36.5282	-84.78	698754	4044825
46	36.541	-84.78	698747	4046250
47	36.5539	-84.78	698733	4047677

Table 7 (continued). Photo Centers — Recorded on October 11, 2003.

frame	lat	long	UTM X	UTM Y
48	36.5667	-84.779	698735	4049107
49	36.5796	-84.779	698748	4050538
50	36.5925	-84.778	698793	4051963
51	36.6054	-84.777	698831	4053397
52	36.6184	-84.777	698820	4054845
53	36.6313	-84.776	698811	4056270
54	36.645	-84.776	698769	4057791
55	36.631	-84.747	701414	4056299
56	36.618	-84.748	701403	4054864
57	36.6052	-84.749	701361	4053440
58	36.5922	-84.749	701321	4051993
59	36.5794	-84.75	701310	4050572
60	36.5663	-84.75	701341	4049123
61	36.5535	-84.75	701364	4047695
62	36.5406	-84.751	701354	4046269
63	36.5275	-84.752	701302	4044810
64	36.5147	-84.753	701234	4043385
65	36.5016	-84.753	701242	4041934
66	36.4887	-84.753	701274	4040499
67	36.4758	-84.753	701317	4039071
68	36.4629	-84.753	701324	4037641
69	36.4498	-84.754	701313	4036185
70	36.4369	-84.754	701301	4034750
71	36.424	-84.755	701257	4033314
72	36.4109	-84.756	701219	4031870
73	36.3979	-84.756	701213	4030416
74	36.3848	-84.756	701241	4028967
75	36.3717	-84.757	701259	4027512
76	36.3587	-84.757	701236	4026069
77	36.3456	-84.758	701194	4024610
78	36.3325	-84.759	701168	4023158
79	36.3195	-84.758	701219	4021714
80	36.3064	-84.758	701270	4020261
81	36.2933	-84.759	701234	4018816
82	36.3035	-84.734	703476	4019999
83	36.3166	-84.733	703485	4021452
84	36.3298	-84.733	703482	4022912

Table 7 (continued). Photo Centers — Recorded on October 11, 2003.

frame	lat	long	UTM X	UTM Y
85	36.3429	-84.732	703532	4024367
86	36.356	-84.731	703586	4025820
87	36.3691	-84.73	703612	4027285
88	36.3821	-84.73	703626	4028729
89	36.3952	-84.729	703653	4030184
90	36.4083	-84.729	703619	4031634
91	36.4214	-84.729	703609	4033084
92	36.4344	-84.728	703638	4034528
93	36.4473	-84.727	703672	4035959
94	36.4603	-84.727	703694	4037405
95	36.4732	-84.726	703717	4038842
96	36.4861	-84.726	703728	4040271
97	36.499	-84.725	703756	4041701
98	36.5122	-84.724	703809	4043167
99	36.5251	-84.724	703795	4044607
100	36.5383	-84.724	703778	4046071
101	36.5513	-84.723	703823	4047513
102	36.5643	-84.721	703902	4048959
103	36.5775	-84.722	703863	4050421
104	36.5905	-84.722	703789	4051863
105	36.6034	-84.721	703800	4053297
106	36.6165	-84.72	703896	4054748
107	36.6293	-84.719	703985	4056179
108	36.6425	-84.719	703941	4057641
109	36.6555	-84.719	703915	4059081
110	36.6544	-84.69	706440	4059014
111	36.6413	-84.691	706425	4057564
112	36.6281	-84.692	706410	4056103
113	36.6153	-84.692	706389	4054674
114	36.6022	-84.692	706394	4053219
115	36.5891	-84.692	706440	4051765
116	36.5759	-84.693	706415	4050304
117	36.5629	-84.694	706399	4048866
118	36.5497	-84.694	706395	4047392
119	36.5364	-84.695	706384	4045916
120	36.5233	-84.695	706365	4044463
121	36.5102	-84.696	706354	4043008

Table 7 (continued). Photo Centers — Recorded on October 11, 2003.

frame	lat	long	UTM X	UTM Y
122	36.4973	-84.696	706368	4041576
123	36.4844	-84.696	706379	4040142
124	36.4714	-84.697	706357	4038706
125	36.4582	-84.697	706379	4037241
126	36.4452	-84.697	706395	4035791
127	36.4321	-84.698	706369	4034338
128	36.4192	-84.698	706356	4032908
129	36.4061	-84.699	706343	4031455
130	36.393	-84.7	706310	4029993
131	36.3797	-84.7	706300	4028524
132	36.3665	-84.7	706311	4027060
133	36.3533	-84.7	706348	4025589
134	36.3402	-84.701	706357	4024142
135	36.3271	-84.701	706323	4022677
136	36.3343	-84.674	708793	4023544
137	36.3476	-84.673	708820	4025013
138	36.3609	-84.672	708846	4026489
139	36.374	-84.672	708841	4027952
140	36.3871	-84.672	708842	4029407
141	36.4002	-84.671	708834	4030861
142	36.4133	-84.671	708867	4032311
143	36.4264	-84.67	708893	4033771
144	36.4395	-84.67	708804	4035216
145	36.4526	-84.67	708806	4036674
146	36.4658	-84.669	708862	4038136
147	36.4788	-84.668	708900	4039580
148	36.4919	-84.668	708879	4041038
149	36.5049	-84.668	708874	4042477
150	36.5179	-84.667	708900	4043929
151	36.531	-84.667	708901	4045384
152	36.5442	-84.666	708897	4046849
153	36.5574	-84.666	708910	4048308
154	36.5706	-84.665	708932	4049775
155	36.5837	-84.665	708936	4051235
156	36.597	-84.664	708946	4052713
157	36.61	-84.664	708950	4054156
158	36.6232	-84.663	708958	4055620

Table 7 (continued). Photo Centers — Recorded on October 11, 2003.

frame	lat	long	UTM X	UTM Y
159	36.6363	-84.663	708929	4057073
160	36.6494	-84.663	708913	4058524
161	36.6624	-84.662	708930	4059969
162	36.6759	-84.661	709002	4061464
163	36.6769	-84.631	711663	4061641
164	36.6635	-84.632	711631	4060161
165	36.6504	-84.633	711575	4058702
166	36.6372	-84.634	711542	4057236
167	36.6242	-84.634	711562	4055794
168	36.6109	-84.634	711606	4054320
169	36.5979	-84.634	711609	4052870
170	36.5848	-84.635	711578	4051422
171	36.5717	-84.636	711539	4049958
172	36.5584	-84.636	711576	4048490
173	36.5454	-84.636	711632	4047043
174	36.5322	-84.636	711628	4045582
175	36.5192	-84.637	711580	4044134
176	36.506	-84.638	711550	4042668
177	36.4927	-84.638	711551	4041194
178	36.4798	-84.638	711576	4039758
179	36.4669	-84.639	711572	4038327
180	36.4538	-84.639	711553	4036868
181	36.4407	-84.64	711528	4035415
182	36.4277	-84.641	711518	4033974
183	36.4145	-84.641	711547	4032512
184	36.4016	-84.641	711569	4031074
185	36.3885	-84.641	711561	4029620
186	36.3754	-84.642	711529	4028167
187	36.3623	-84.643	711478	4026711
188	36.3492	-84.644	711445	4025258
189	36.356	-84.615	714012	4026077
190	36.3692	-84.615	713988	4027539
191	36.3823	-84.615	713970	4028995
192	36.3954	-84.614	713990	4030450
193	36.4084	-84.613	714026	4031897
194	36.4215	-84.612	714051	4033352
195	36.4346	-84.612	714065	4034802

Table 7 (continued). Photo Centers — Recorded on October 11, 2003.

frame	lat	long	UTM X	UTM Y
196	36.4477	-84.612	714047	4036253
197	36.4608	-84.611	714051	4037715
198	36.4738	-84.611	714051	4039157
199	36.4867	-84.61	714053	4040583
200	36.4996	-84.61	714053	4042021
201	36.5126	-84.609	714083	4043465
202	36.5257	-84.609	714106	4044914
203	36.5387	-84.609	714074	4046357
204	36.5518	-84.609	714039	4047814
205	36.5651	-84.608	714048	4049289
206	36.5784	-84.607	714079	4050766
207	36.5918	-84.607	714109	4052254
208	36.6052	-84.606	714125	4053743
209	36.6184	-84.606	714128	4055215
210	36.6317	-84.606	714085	4056688
211	36.6449	-84.605	714101	4058152
212	36.658	-84.604	714125	4059613
213	36.6714	-84.604	714135	4061095
214	36.6847	-84.603	714131	4062569
215	36.8299	-84.569	716793	4078762
216	36.8164	-84.57	716733	4077260
217	36.803	-84.571	716673	4075770
218	36.7896	-84.572	716667	4074279
219	36.7761	-84.572	716705	4072784
220	36.7627	-84.572	716725	4071296
221	36.7492	-84.573	716713	4069803
222	36.7359	-84.573	716686	4068317
223	36.7226	-84.574	716665	4066848
224	36.7094	-84.574	716692	4065376
225	36.6959	-84.574	716701	4063882
226	36.6826	-84.575	716715	4062400
227	36.6694	-84.575	716696	4060940
228	36.6561	-84.576	716676	4059460
229	36.6429	-84.576	716677	4057992
230	36.6297	-84.577	716690	4056527
231	36.6163	-84.577	716718	4055041
232	36.6028	-84.577	716732	4053540

Table 7 (continued). Photo Centers — Recorded on October 11, 2003.

frame	lat	long	UTM X	UTM Y
233	36.5894	-84.578	716709	4052059
234	36.5762	-84.579	716644	4050585
235	36.5628	-84.58	716605	4049102
236	36.5497	-84.58	716616	4047651
237	36.5368	-84.58	716626	4046214
238	36.5239	-84.58	716650	4044782
239	36.5109	-84.58	716692	4043339
240	36.4979	-84.58	716715	4041895
241	36.4849	-84.581	716702	4040456
242	36.472	-84.581	716694	4039024
243	36.459	-84.582	716656	4037577
244	36.4461	-84.583	716636	4036142
245	36.4331	-84.583	716667	4034705
246	36.4201	-84.583	716701	4033263
247	36.407	-84.584	716685	4031801
248	36.3939	-84.584	716665	4030350
249	36.3808	-84.585	716660	4028897
250	36.3679	-84.585	716683	4027459
251	36.3552	-84.585	716708	4026058
252	36.363	-84.557	719149	4026985
253	36.376	-84.557	719179	4028431
254	36.3891	-84.556	719198	4029878
255	36.4022	-84.556	719145	4031337
256	36.4153	-84.556	719110	4032788
257	36.4285	-84.556	719111	4034254
258	36.4413	-84.555	719167	4035677
259	36.4543	-84.554	719224	4037121
260	36.4672	-84.553	719239	4038548
261	36.4801	-84.553	719231	4039983
262	36.4931	-84.553	719206	4041428
263	36.5061	-84.552	719194	4042873
264	36.5191	-84.552	719217	4044311
265	36.5319	-84.551	719217	4045741
266	36.545	-84.551	719214	4047189
267	36.558	-84.551	719204	4048628
268	36.571	-84.55	719236	4050079
269	36.5841	-84.549	719276	4051536

Table 7 (continued). Photo Centers — Recorded on October 11, 2003.

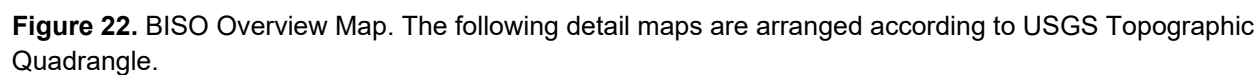
frame	lat	long	UTM X	UTM Y
270	36.5972	-84.549	719265	4052992
271	36.6105	-84.549	719250	4054466
272	36.6239	-84.548	719264	4055952
273	36.6374	-84.547	719279	4057446
274	36.6509	-84.547	719272	4058945
275	36.6643	-84.547	719221	4060437
276	36.6778	-84.546	719258	4061933
277	36.6912	-84.545	719311	4063429
278	36.7047	-84.544	719349	4064930
279	36.7182	-84.545	719260	4066422
280	36.7317	-84.545	719258	4067920
281	36.745	-84.544	719275	4069398
282	36.7585	-84.544	719272	4070892
283	36.772	-84.543	719283	4072393
284	36.7856	-84.543	719283	4073910
285	36.7991	-84.542	719286	4075401
286	36.8125	-84.542	719291	4076893
287	36.8259	-84.541	719292	4078383
288	36.8394	-84.541	719309	4079878
289	36.8338	-84.511	721980	4079330
290	36.8207	-84.512	721953	4077867
291	36.8073	-84.512	721951	4076379
292	36.7939	-84.513	721933	4074895
293	36.7805	-84.513	721927	4073413
294	36.767	-84.513	721956	4071906
295	36.7537	-84.514	721958	4070429
296	36.7402	-84.514	721927	4068938
297	36.7268	-84.515	721907	4067446
298	36.7134	-84.515	721915	4065960
299	36.7	-84.516	721914	4064465
300	36.6866	-84.517	721875	4062975
301	36.673	-84.517	721925	4061475
302	36.6597	-84.516	721995	4059995
303	36.6462	-84.517	721998	4058497
304	36.633	-84.517	721988	4057030
305	36.6198	-84.518	721939	4055563
306	36.6065	-84.519	721877	4054082

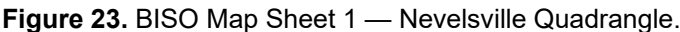
Table 7 (continued). Photo Centers — Recorded on October 11, 2003.

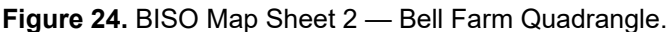
Frame	lat	long	UTM X	UTM Y
307	36.5932	-84.52	721834	4052610
308	36.5799	-84.521	721822	4051135
309	36.5667	-84.521	721824	4049668
310	36.5422	-84.521	721884	4046942
311	36.5397	-84.521	721901	4046670
312	36.5364	-84.521	721931	4046306
313	36.5339	-84.521	721959	4046032
314	36.5311	-84.52	722001	4045720
315	36.5288	-84.52	722045	4045462
316	36.5264	-84.519	722096	4045204
317	36.5236	-84.519	722167	4044889
318	36.5209	-84.518	722240	4044592
319	36.5177	-84.517	722332	4044236
320	36.4961	-84.51	723056	4041859
321	36.3963	-84.568	718142	4030653

Appendix B. Digital Vegetation Maps of the Big South Fork National River and Recreation Area

Appendix B contains images of all of the digital vegetation maps for BISO (Figures 22 to 34). Maps are based off of USGS quadrangles.









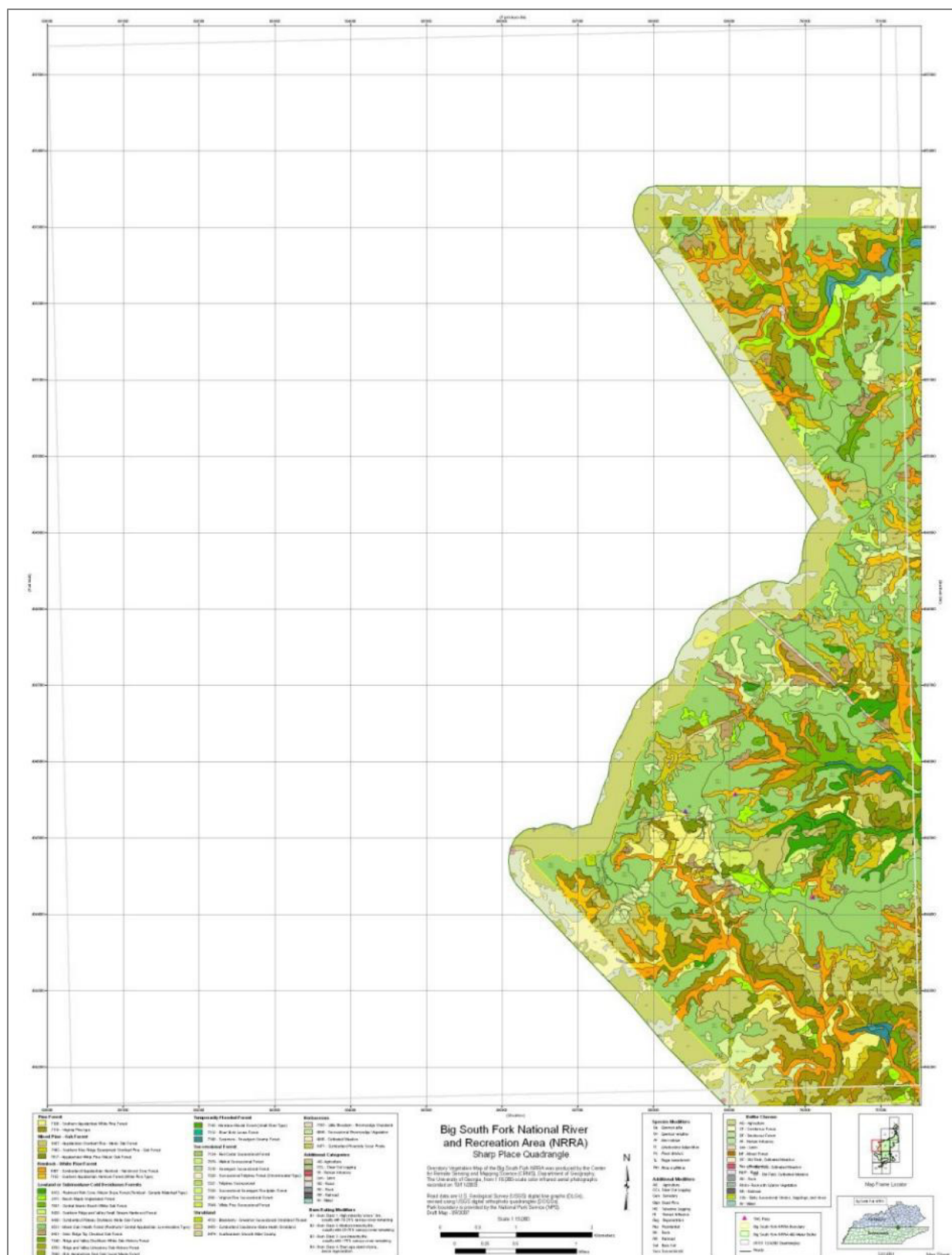


Figure 26. BISO Map Sheet 4 — Sharp Place Quadrangle.

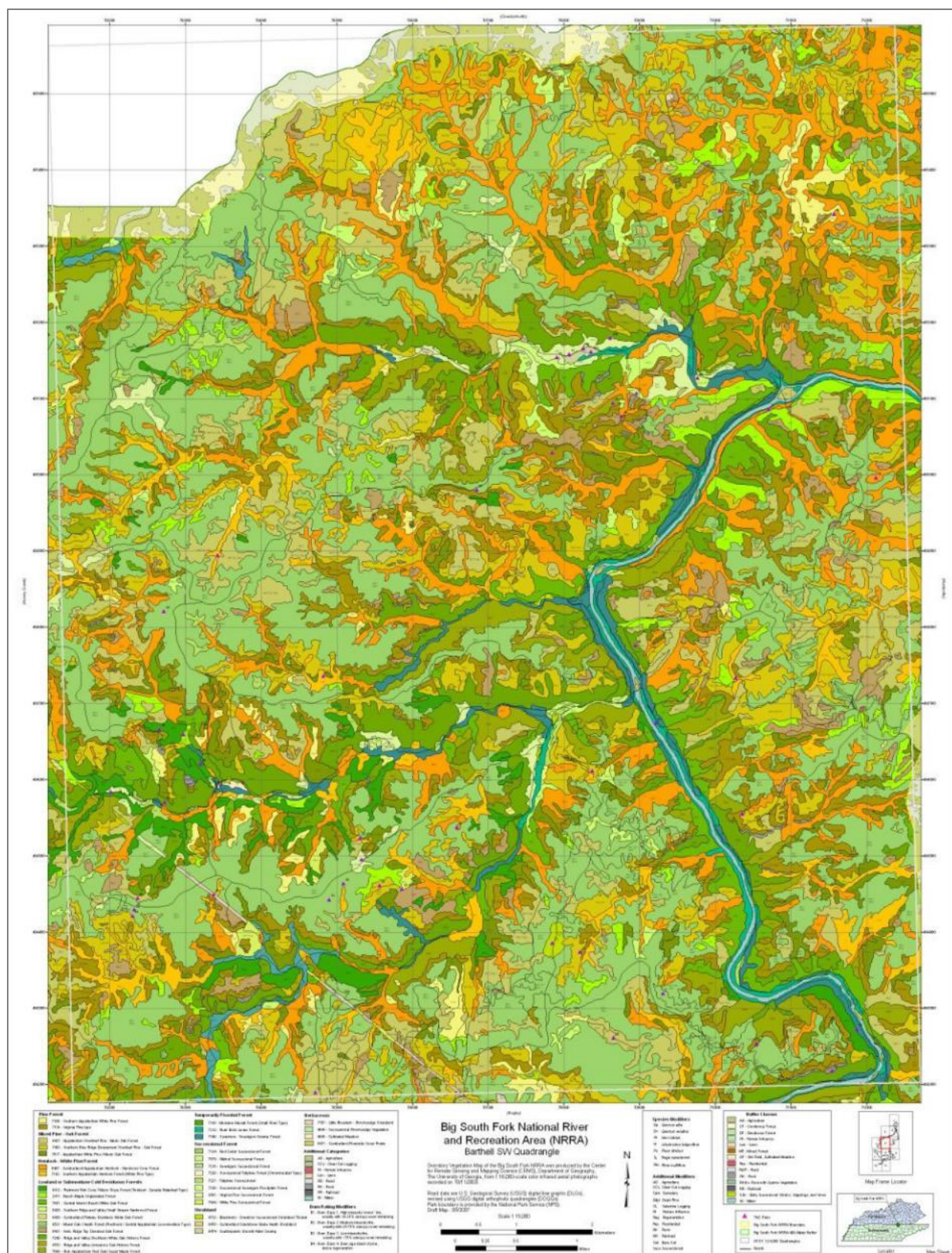
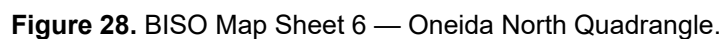


Figure 27. BISO Map Sheet 5 — Barthell SW Quadrangle.



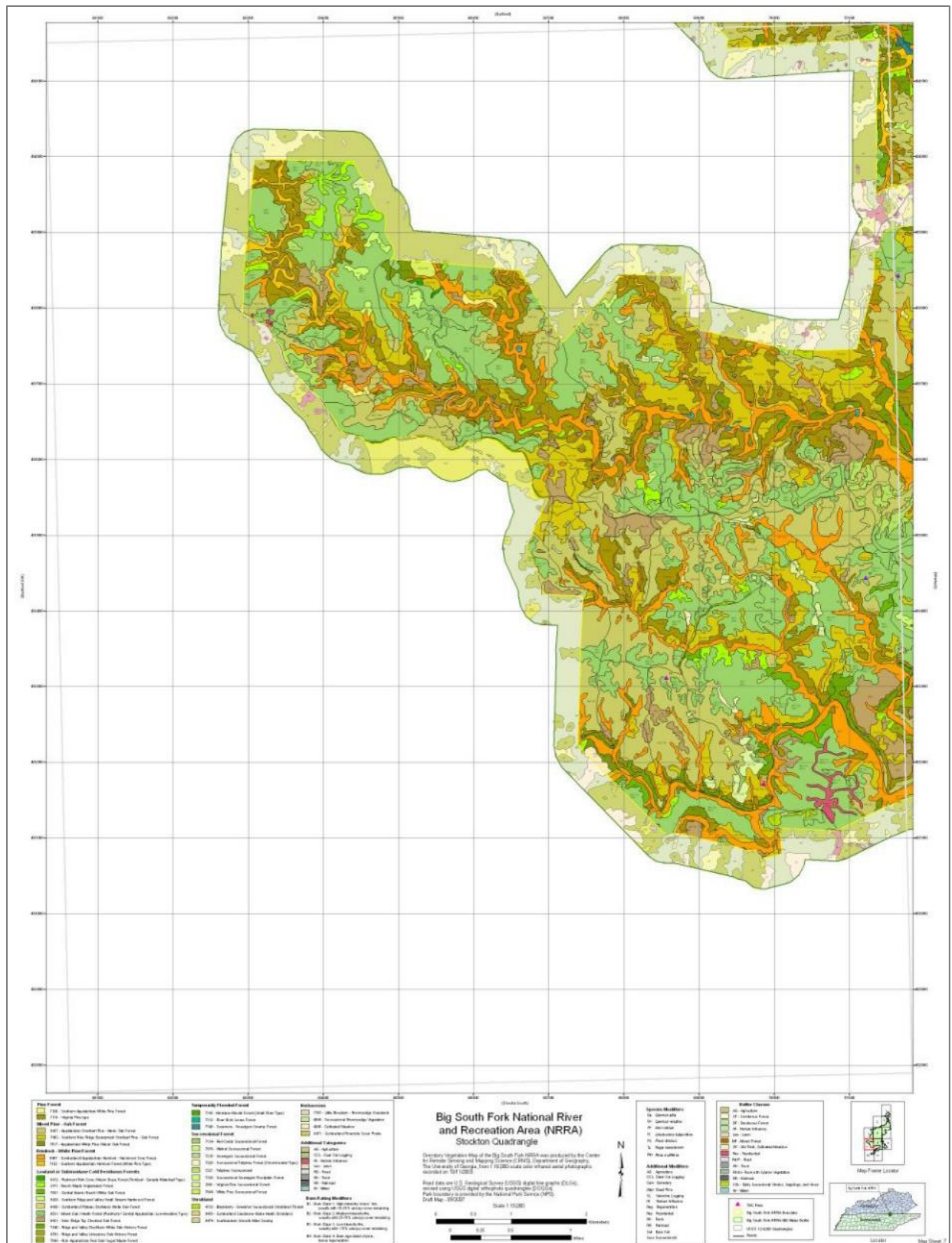


Figure 29. BISO Map Sheet 7 — Stockton Quadrangle.

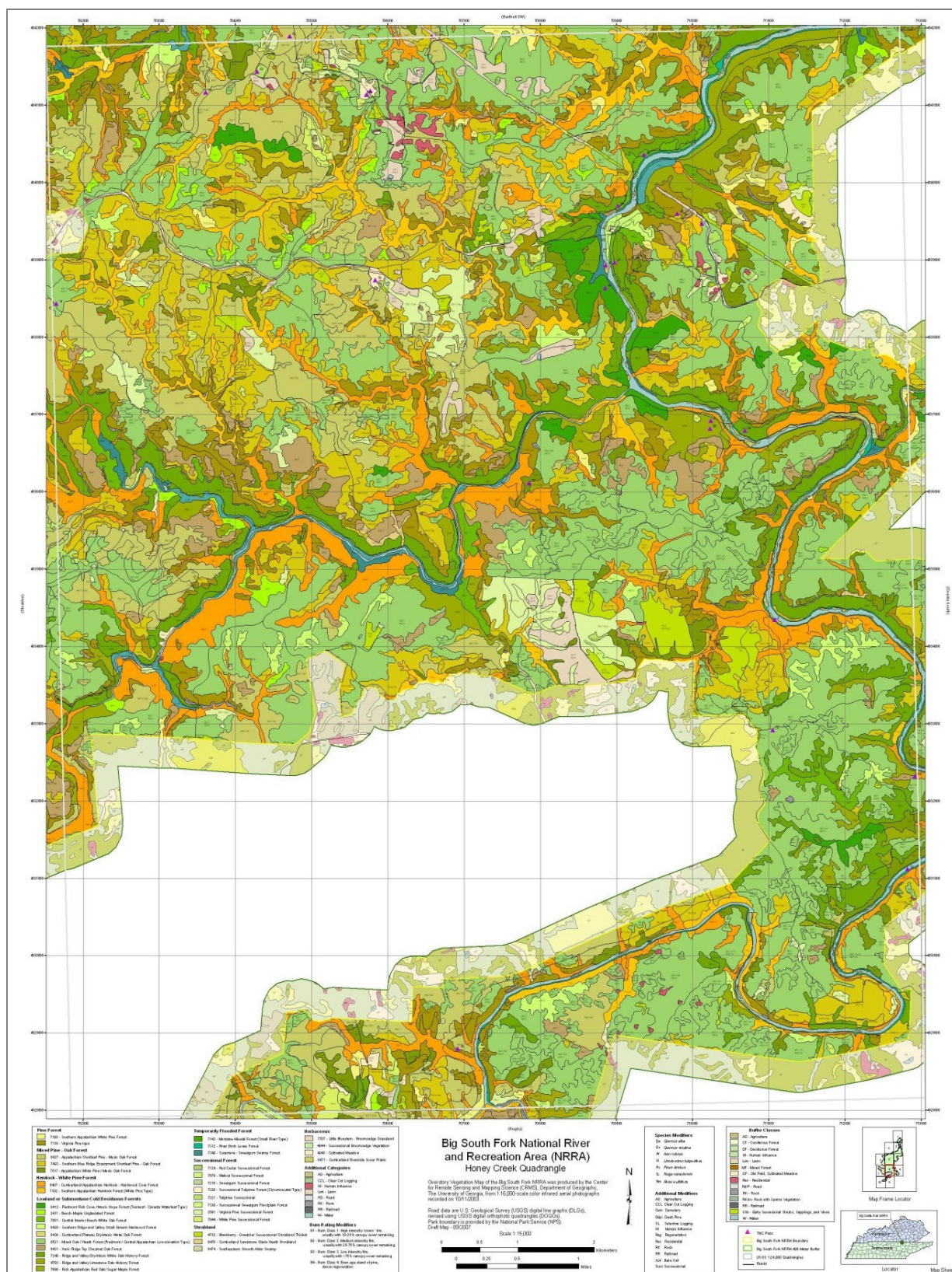




Figure 32. BISO Map Sheet 10 — Burville Quadrangle.

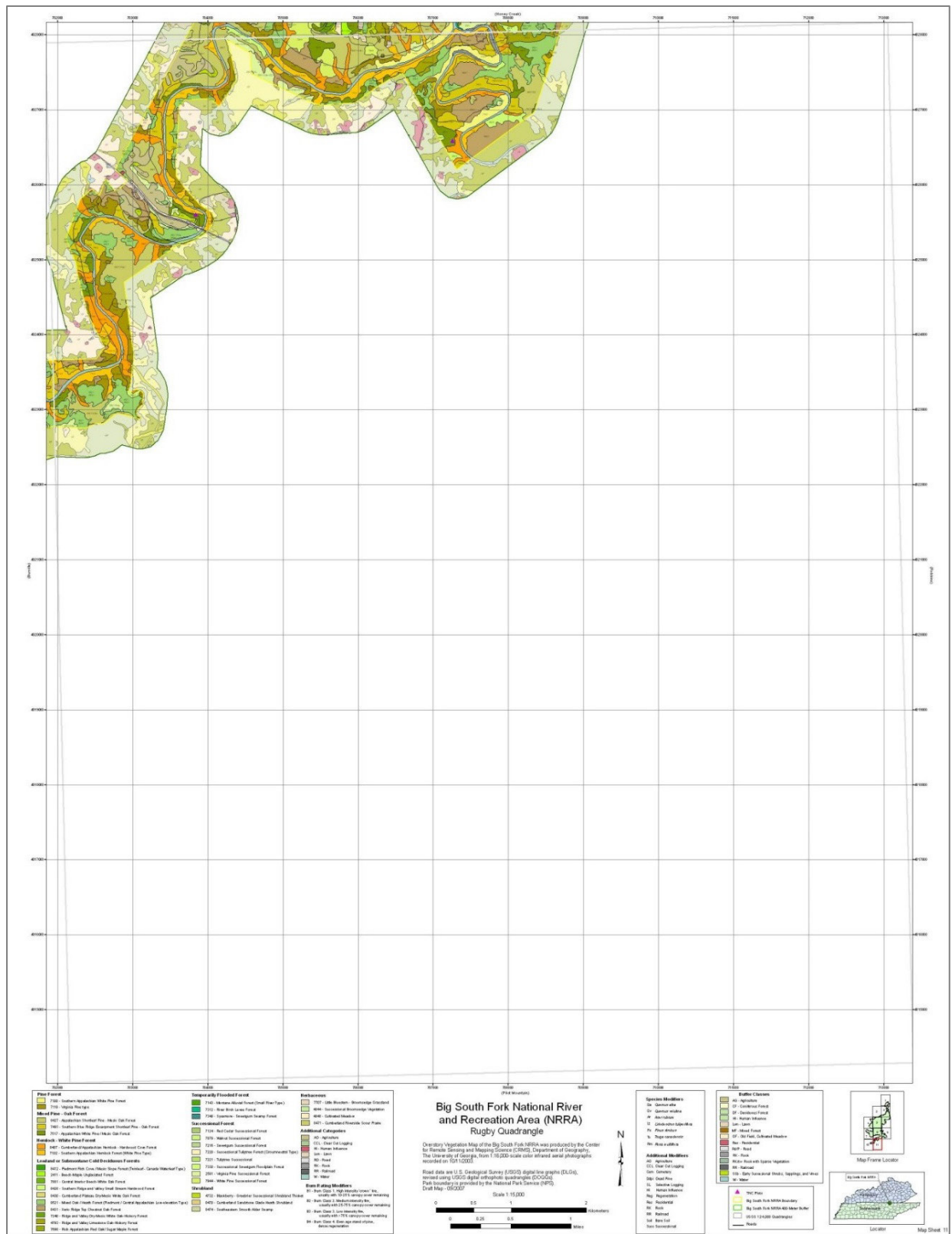


Figure 33. BISO Map Sheet 11 — Rugby Quadrangle.

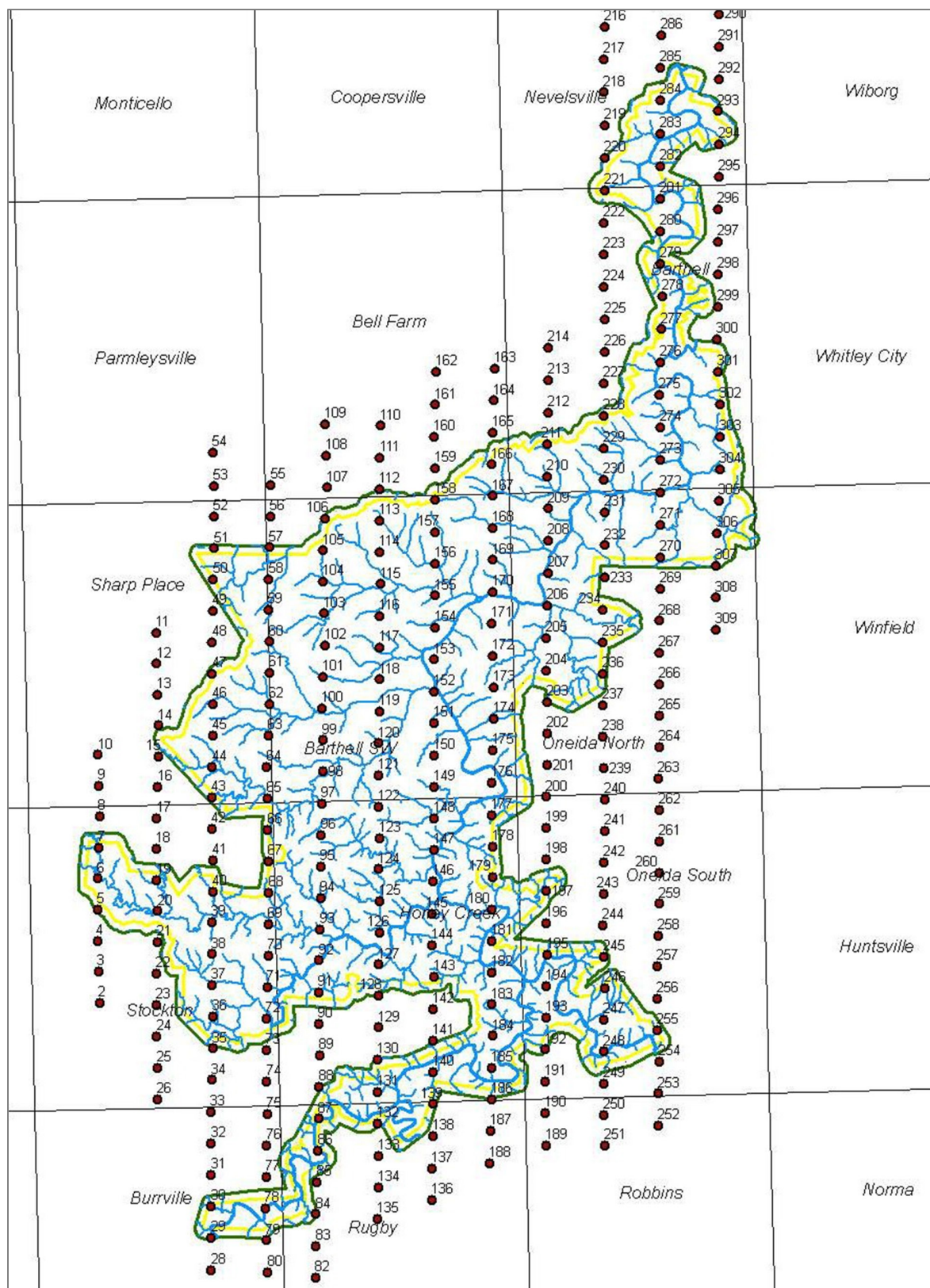


Figure 34. Aerial photograph photo index map. 1:16,000 scale aerial photographs were acquired by Air Photographics, Inc. (Martinsburg, WV) on October 11, 2003.

National Park Service
U.S. Department of the Interior



Science Report NPS/SR—2024/199
<https://doi.org/10.36967/2305475>

Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525