WETLAND RESOURCE CHARACTERIZATION OF THE CONGAREE SWAMP NATIONAL MONUMENT, SOUTH CAROLINA:

Database Preparation Based on Remotely Sensed Data for Use in Geographic Information Systems

FINAL PROJECT REPORT FOR THE
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NATIONAL PARK SERVICE

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Government Technical Representative:
Richard A. Clark, Chief
Research and Resources Management

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Prepared by:
South Carolina Department of Natural Resources
Land Resources and Conservation Districts Division
(formerly: S.C. Land Resources Conservation Commission)
Southeastern Remote Sensing Center

Principal Investigators:
Richard B. Lacy
Robert C. Somers, Ph.D.

Co-Principal Investigators:
Thomas P. Curley
Benjamin C. Jones
John R. Wisdom

Project Contributors:
Eric L. Dobson
Francois G.F. Smith

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Executive Summary

The project entitled "Wetland Resource Characterization of the Congaree Swamp National Monument, South Carolina: Database Preparation Based on Remotely Sensed Data for Use in Geographic Information Systems" was conducted under Cooperative Agreement #CA-5000-2-9010 between the United States Department of Interior (USDOI), National Park Service (NPS), and the South Carolina Department of Natural Resources (SCDNR), Land Resources and Conservation Districts (LRCD) Division (formerly S.C. Land Resources Conservation Commission), Southeastern Remote Sensing Center.

Congaree Swamp National Monument is a 22,200-acre old-growth bottomland hardwood forest located in the floodplain of the Congaree River southeast of Columbia, South Carolina (Clark and Dawson, 1992). The Monument contains a complex and varied pattern of vegetative communities resulting from minor changes in elevation related to the geomorphologic process of river meandering through time and flooding frequency and duration. Flooding occurs naturally from the Broad and Saluda Rivers, major tributaries of the Congaree, draining upstream watersheds, and from water releases at the Lake Murray Dam, 20 miles upstream of the Monument on the Saluda River.

A comprehensive characterization of wetland resources within the Monument is needed to provide an updated bottomland forest inventory, to establish a baseline of information for future management efforts and to prepare a composite of data sources for combination and analysis to assist in making vegetative community determinations. This digital database includes U.S. Fish and Wildlife Service (USFWS), National Wetlands Inventory (NWI); U.S. Department of Agriculture (USDA), Natural Resource Conservation Service (NRCS), Richland County, South Carolina, soil survey; U.S. Geological Survey (USGS), Water Resources Division (WRD), surface hydrologic and topographic features; G.A. Smathers (1980) vegetative communities; SPOT image derived land use/land cover; USGS digital line graphs (DLG); park trails; record trees; forest sampling plots; pre- and post-Hurricane Hugo color infrared National Aerial Photography Program (NAPP) scans; Landsat Thematic Mapper (TM) and SPOT multispectral satellite imagery; ground control points; and the legal Monument boundary. A remote sensing based geographic information system (GIS) database was produced from highly disparate information sources useful for ecological questions and management issues in the Monument. This intense effort at reconciling and coordinating large quantities of previously incompatible data provides a baseline wetland inventory for the Monument needed by National Park personnel to monitor and manage the Nation's valuable resource assets.

The SCDNR/LRCD Division, (hereafter, "Department") has enjoyed an excellent professional relationship with the USDOI/NPS (hereafter, "Service") throughout the life of this project. Research and Resources Management Chief Richard A. Clark, the Government Technical Representative to this project, provided timely guidance and excellent continuity of support to the Principal Investigators. The Department takes this opportunity to express its appreciation to the Service for the exceptional representation and liaison role provided by Mr. Clark.

Introduction

Congaree Swamp National Monument was designated by enabling legislation "to preserve and protect for the education, inspiration, and enjoyment of present and future generations an outstanding example of a near-virgin southern hardwood forest situated in the Congaree River floodplain in Richland County, South Carolina" (PL-94-545, October 16, 1976). After establishment as a unit of the National Park Service in 1976, this valuable national landmark was awarded global significance in 1983 upon inclusion in the UNESCO International Network of Biosphere Reserves within the South Atlantic Coastal Plain Biosphere Reserve. In addition, the Monument's prospective designation as a World Heritage Site and its status as a benchmark resource for long-term change monitoring make it a unique place for ecological research and environmental education (Clark and Dawson, 1992).

The Congaree Swamp is a bottomland hardwood forest with relatively little topographic relief composed of meandering creeks, sloughs and swales, oxbow lakes and generally hydric silty clay soils whose major source of flood waters, sediments and nutrients is the Congaree River. The uncut portions of the Swamp form the most extensive mature bottomland forest remaining in the southeastern United States (Clark and Dawson, 1992). Significant aspects of the Swamp include its unique bottomland hardwood forest community located in a sizeable (13 by 5 miles) floodplain with distinct former river courses reflected in its topography and vegetative patterns, its giant trees such as bald cypress, water tupelo, swamp tupelo, loblolly pine, sweetgum, sycamore, cottonwood, oak and holly, and its hardwood swamp ecology supporting viable fauna. The Swamp's hardwood forest supports a diverse plant community (87 tree species) with many trees measuring at least 80% of national and state record size, including loblolly pines over 150 feet in height.

Bottomland hardwood communities support distinct associations of flora and fauna which vary with the subtle variations in landform, hydrology and soils found in floodplains related to micro-elevational differences across the terrain (Wharton et al., 1982). These bottomland forests comprise extremely productive and diverse riverine communities within ecosystems with fluctuating hydrologic regimes (Odum, 1969). Bottomland hardwood floodplains form transitional gradients along a hydrologic continuum between permanent water and terrestrial upland, making it difficult to delineate discrete vegetative community types.

For these reasons, a comprehensive wetland resource characterization was undertaken by assembling various datasets into a digital information system and by combining them for comparison of possible relationships to vegetative community distribution. The design and assembly of a robust, digital, spatial database for the Monument provided a method of wetland characterization based on hydric soils (USDA/NRCS); hydrophytic vegetation, hydrologic regime and water chemistry (USFWS/NWI); surface hydrologic and topographic features (USGS/WRD); detailed vegetation (Smathers, 1980); satellite image derived land cover; and rectified, digital, air photo and satellite image data.

Background

The Congaree Swamp National Monument represents the last significant stand of old-growth river bottomland hardwood forest in the Southeast and receives periodic and unpredictable flooding from the Congaree River along 24 river miles of its southern boundary. The Broad River is the major contributor to flooding frequency and duration, according to Monument resource management personnel. Water impounded by Lake Murray, a reservoir created by a dam on the Saluda River, and released by the South Carolina Electric and Gas Company, a SCANA subsidiary, influences the magnitude of water entering the Congaree River. Flooding typically occurs when substantial upstream rainfall occurs within the drainage basin and combines with water releases through the Lake Murray dam related to hydroelectric power generation requirements. The Monument experiences an average of 10 floods annually with 75% of the site flooded during each event, while 90% of the Swamp system is flooded at least once a year (Clark and Dawson, 1992).

The Congaree River drainage basin formed by the Broad and Saluda Rivers extends into northwestern South Carolina and western North Carolina with a watershed area of over 8,000 square miles or about 5 million acres. This vast watershed collects accumulated point and nonpoint source pollution from upstream agricultural, forested and urban areas. To date, however, no major surface water pollution problems in the Congaree River or Cedar Creek, its main tributary flowing through the Monument, have been reported (Clark and Dawson, 1992). Furthermore, the Congaree River and Cedar Creek meet eligibility criteria for inclusion in the National Wild and Scenic Rivers System, with the Congaree listed as significant in the Nationwide Rivers Inventory and the Statewide Rivers Assessment.

Forest lands of the Monument have historically, prior to its establishment under the National Park Service, been 24% clear-cut and 13% selectively cut, with the remaining 63% being near-virgin or virgin forest (Clark and Dawson, 1992). In September 1989, Hurricane Hugo with its associated high-velocity winds caused severe damage to the Swamp forest: 49% of the trees in the bottomland hardwood forest and 19% of the trees in the sloughs were "seriously damaged" (Putz and Sharitz, 1991, Canadian Journal of Forest Research 21: 1765-1770). The term "seriously damaged" is defined by the latter authors as either (1) the loss of more than 25% of the tree crown, (2) snapping of the trunk, or (3) uprooting of the tree. The overall effect of the storm was a dispersed pattern of tree blow-down throughout the entire forest.

Past and present work describing the wetlands in the Monument has been conducted by Dr. L.L. Gaddy (1975, 1977, 1979), G.A. Smathers (1980), R.R. Sharitz (past and current forest dynamics work), and R.H. Jones (current record tree survey) and are closely related to the work of this project. In addition, the project has benefitted substantially from contributions by several resource scientists and managers, including Dr. Bob Somers, Dr. Bob Jones, Dr. Rebecca Sharitz, Mr. Eric Pauley, Mr. Joel Wagner, Ms. Leslie Armstrong, Mr. Frank Draughn, and Mr. Rick Clark.

Project Development

In early 1992, preliminary communications were made between representatives of the USDOI National Park Service (Congaree Swamp National Monument and Southeast Regional Office) and the Land Resources Conservation Commission (now Land Resources and Conservation Districts Division, South Carolina Department of Natural Resources) to explore the feasibility of a partnership in conducting a comprehensive wetland inventory based on remotely sensed data and developing a digital database for the Monument.

Contact was made among Rick Clark (Resource Management Specialist, Congaree Swamp National Monument), Rick Dawson (Regional Water Resources Coordinator, National Park Service Southeast Regional Office), Dr. Robert Somers (Director, Resource Planning Division, SCLRCC) and Richard Lacy (Remote Sensing Manager, Resource Planning Division, SCLRCC).

An advisory team was proposed to include other wetland resource professionals, as follows: Dr. Rebecca Sharitz, Senior Forest Research Ecologist, and Allen Cook, GIS/Remote Sensing Specialist (Savannah River Ecology Laboratory, University of Georgia); Dr. L.L. "Chic" Gaddy, private consultant in wetland biota; Dr. Bob Jones, School of Forestry (Auburn University); John Hefner, Regional Coordinator, National Wetlands Inventory (U.S. Fish and Wildlife Service, Atlanta); Joe Meyer and, later, Frank Draughn, Regional GIS Coordinators (National Park Service, Southeast Regional Office).

Upon establishment of a cooperative agreement between the Service and the Department, a strategic planning meeting was held at state offices in Columbia, South Carolina, which included project principals and advisors. Participants discussed the value and feasibility of various approaches and work plans that might be required to produce a viable comprehensive wetland resource characterization, to include wetland related layers of information in a digital database.

The Department became involved in this cooperative agreement with the Service based upon the expertise of its professional staff which has a commitment to study land cover and land use in the State of South Carolina. Areas of expertise include: (1) wetland inventory and mapping; (2) floodplain management and protection; (3) remote sensing and geographic information systems (GIS); and (4) natural resource enhancement, conservation and education.

As part of the cooperative agreement, the Department agreed to: (1) make available to the Service the use of aerial photographs, satellite imagery, digital datasets, maps, reports, GIS/image processing facilities and related services; (2) commit appropriate staff consultation services to the Service on natural resource management related remote sensing and GIS; and (3) provide the Service with comprehensive reports, project papers, and research data generated from this project.

Image based data made available to the Service by the Department include: (1) pre- and post-Hurricane Hugo (1989 and 1991) color infrared National Aerial Photography Program (NAPP) transparencies, (2) SPOT multispectral imagery (1988-1990), and (3) Landsat Thematic Mapper (TM) multispectral imagery (1990-1992). In addition, natural resource map based data made available by the Department from a variety of sources include: (1) general land cover, (2) soils, (3) NWI, (4) surface hydrologic features, (5) elevation, and (6) vegetation (Smathers, 1980). These layers are useful in a digital format for the database of the Monument, show correspondence between wetland related datasets and enhance wetland characterization across the study site.

The Department houses the USGS Earth Science Information Center (ESIC) state affiliate office for South Carolina, formerly National Cartographic Information Center (NCIC). The South Carolina ESIC office, the Land Resource Information Center (LRIC), serves as the active repository for land related and map based information with sales, reference and outreach components. The LRIC serves as the reference facility for the National High Altitude Photography (NHAP) program and the National Aerial Photography Program (NAPP). The LRIC is also designated as the distribution center for National Wetlands Inventory (NWI) data in South Carolina by the U.S. Fish and Wildlife Service, providing paper and mylar NWI products to the public at a nominal cost.

The Department also houses the Southeastern Remote Sensing Center (SERSC) which has been involved in satellite image analysis since 1977 in partnership with NASA regional centers. Since 1985, the Department has performed its own digital image processing based projects related to land resource monitoring and analysis in cooperation with federal, state, regional and local government agencies, non-government organizations (NGO), private firms, university researchers and the general public.

These Centers provided support to this project in the form of analog and digital data products and provided personnel conversant in air photo interpretation, image analysis, database design, GPS coordinate acquisition and mapping, soils interpretation, forest management and wetland delineation.

Under the subagreement for this project, all major work components and deliverables have been performed with the exception of trend analysis of Hurricane Hugo damage. A Hurricane Hugo damage assessment could not be made because clear patterns of disturbance could not be detected and measured by using the scanned NAPP data. It was originally assumed that the 20,000 foot altitude of photo acquisition aircraft and the production of 1:40,000 nominal scale color infrared datasets would provide sufficient resolution to determine the extent and distribution of storm damage. It was discovered during the course of the project, however, that lower altitude data may be required for interpretation of vegetative disturbance related to Hurricane activity. Optimal image data would be aircraft-borne multispectral-to-hyperspectral (numerous spectral bands or information channels) data. Exact differences between storm disturbance and natural, pre-hurricane complexity of swamp terrain proved impossible to quantify reliably.

Methods

As a result of the early project principals and advisors meeting, an original series of project components was developed by the Department as potentially deliverable to the Service. In general, the Department committed to a scope of work providing various remotely sensed and GIS data layers to facilitate project planning, environmental review and analysis, on-ground orientation and computer enhanced public education capabilities. Anticipated GIS layers included scanned color infrared aerial photography, soils, Smathers (1980) vegetation map, adjacent land use as derived from satellite imagery, the Gadsden and Wateree NWI maps, infrastructural and hydrographic features associated with the USGS DLGs, GPS-surveyed trails and paths, ground control point (GCP) locations and other research related plot locations, record trees and natural features of interest.

Specific tasks as outlined in the initial scope of work include the following:

(1) collection of GCPs using GPS technology acquired for the Service;

(2) scanning of 1989 NAPP and 1991 S.C. Forestry Commission post-Hurricane Hugo color infrared transparencies;

(3) digitizing of infrastructural elements and hydrographic features from USGS 7.5-minute, 1:24,000-scale topographic quadrangle maps for the Monument (Gadsden and Wateree);

(4) digitizing of Smathers (1980) vegetation map and co-registration to GCP base;

(5) GPS surveying of selected trails and incorporation into the database;

(6) georectification of the scanned 1989 NAPP photo data to the GCPs and processing of the NAPP data into discrete vegetative community types comprised of cypress/tupelo and bottomland hardwood wetland communities;

(7) georectification of satellite imagery to the GCPs, classify satellite data for upland area adjacent to the Swamp using Anderson et al. (1976) system to Level I, and mosaic 1989 NAPP wetland community classification with satellite derived upland cover classification;

(8) digitizing of flood zone maps and a 2-foot contour map of the Monument obtained from the USGS Water Resources Division office in Columbia, South Carolina;

(9) digitizing of SCS soils and NWI maps;

(10) repetition of project components 6 and 7 using 1991 post-Hugo color infrared aerial photography;

(11) development of a shadow map from 1991 post-Hugo scanned aerial photography and identification of open-canopied blow-down areas;

(12) groundtruthing of the classified scanned 1989 NAPP based wetland community types and correction of the dataset as needed, and of the 1991 post-Hugo NAPP based wetland community types and dataset correction as needed;

(13) incorporation into the database of permanent forest dynamics study plot boundaries provided by the Savannah River Ecology Laboratory (SREL) and record or champion trees provided by Auburn University researchers;

(14) preparation of a draft GIS database for presentation to the Service;

(15) presentation of the final GIS database to the Service including a computerized public education program that highlights aspects of the GIS; and

(16) the final project report (with trend analysis of Hugo damage and watershed relationships to vegetative communities) outlining significant achievements, progress impediments, meaningful findings and recommendations for future work, software packages, hardware platforms and related investigations for optimal utilization and further enhancement of these project results.

Data Layers

The Congaree Swamp National Monument authorized boundary was provided on a map by the National Park Service, Southeast Regional office in Atlanta. This boundary was digitized into a computer file for use as a "cookie-cutter" of other digital datasets extending beyond the Monument's immediate confines (Figure 1). All acreage and percent of area figures calculated for various Monument resources are relative to this boundary file (Figure 2).

Approximately 115 ground control point (GCP) coordinate pairs (eastings and northings) were collected using Trimble Pathfinder Basic Plus global positioning system (GPS) equipment (Figure 2). Accuracy was within 5 meters after differential correction using the U.S. Forest Service base station in Columbia, South Carolina. The GCPs were used for the geometric correction of digital air photo and satellite image data assembled and analyzed during the study. This process of digital image rectification removed most of the distortion from the aerial data. The GCPs were identified in the imagery, located in the field, described by latitude and longitude, and subsequently converted to Zone 17 Universal Transverse Mercator (UTM) coordinates.

A GPS survey of the entire 20-mile Monument trail system was performed including annotated locations of points of interest along the boardwalks (Figure 3). Using the streaming-mode as UTM coordinates were collected, highly-accurate continuous vectors along all trails were produced. These were incorporated into the Monument database for future use in educational visitor programs and as a reference for park managers and scientists.

Figure 1.

LOCATION OF THE CONGAREE SWAMP NATIONAL MONUMENT

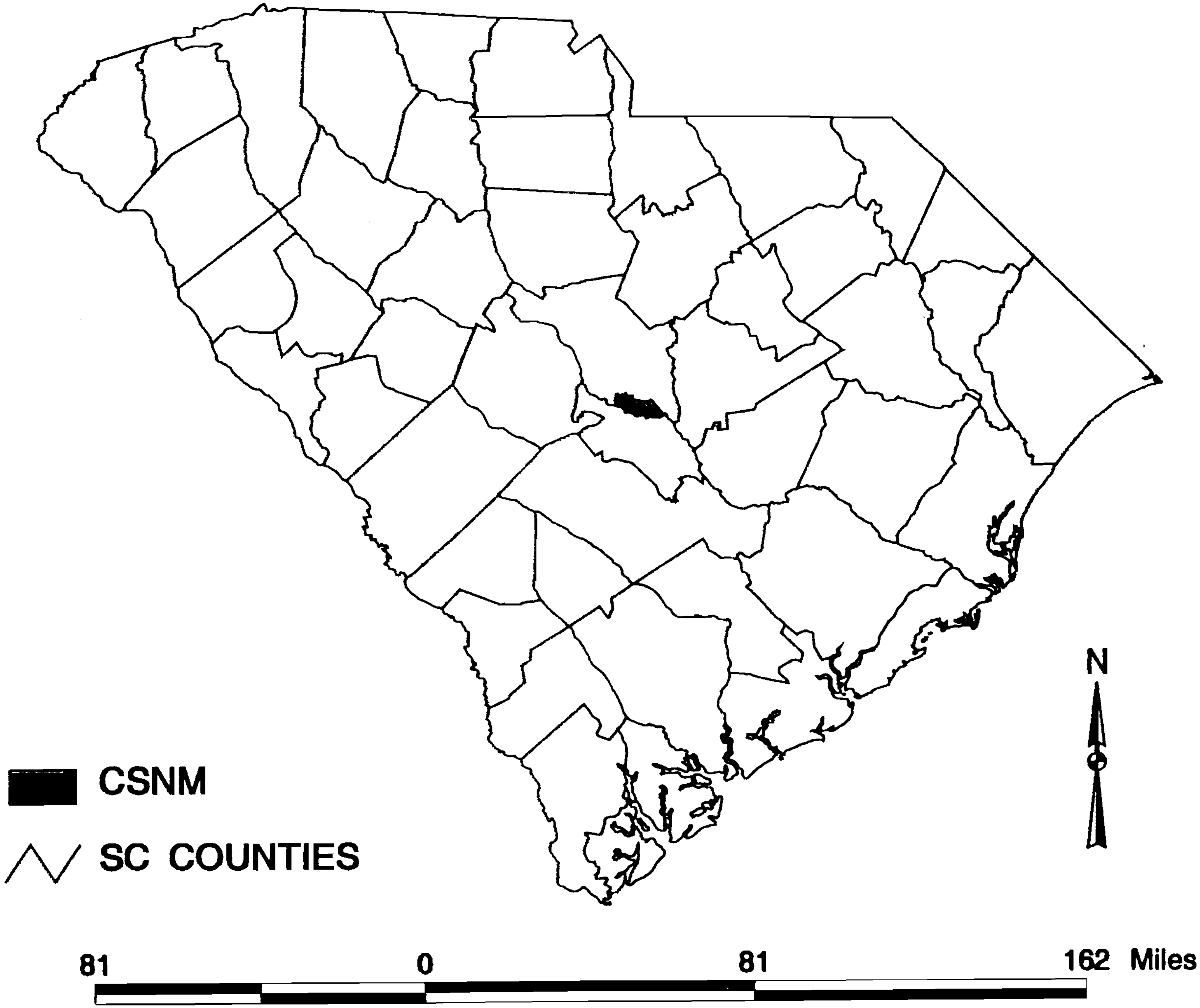


Figure 2.

CSNM BOUNDARY & TRAILS & GCPS

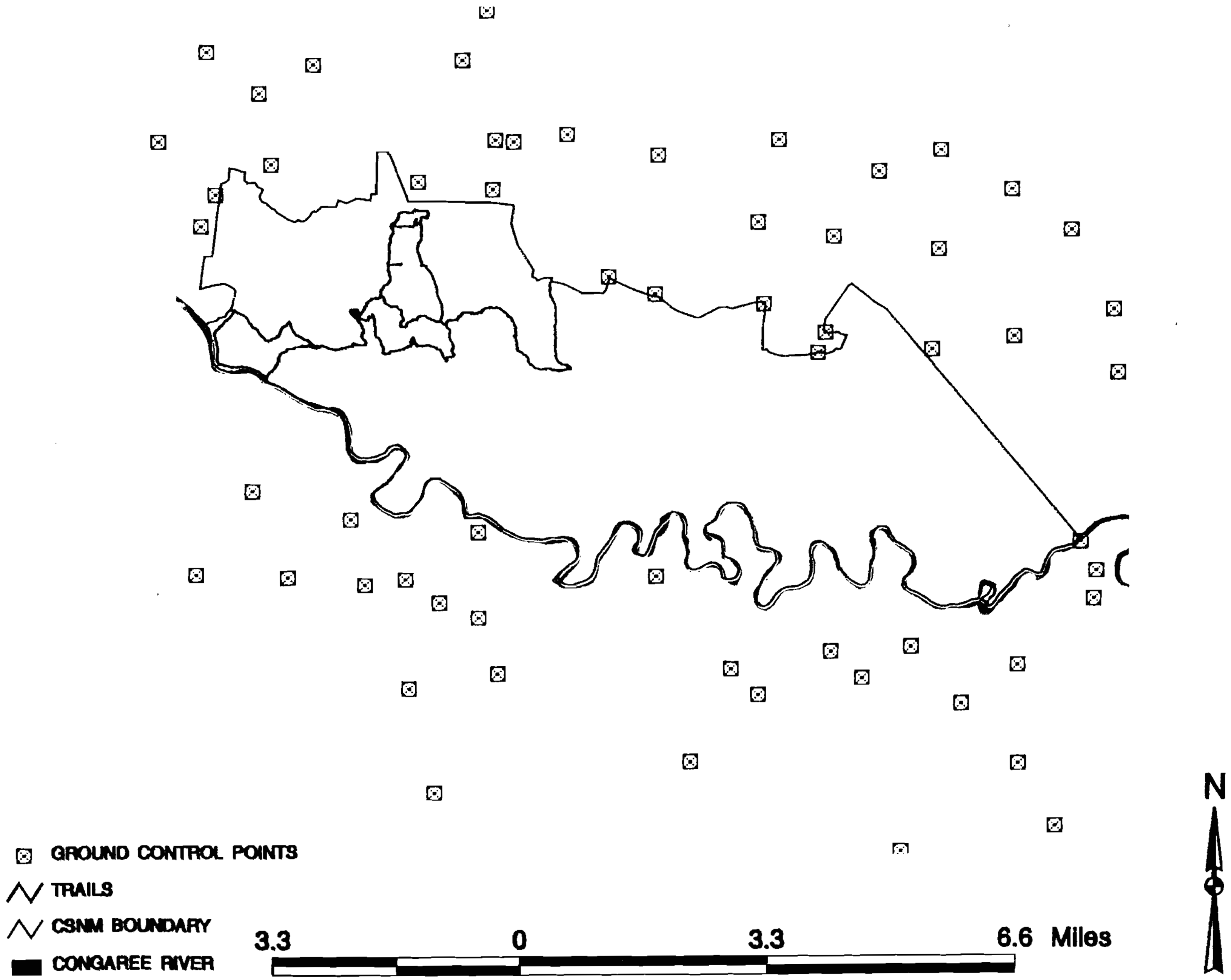
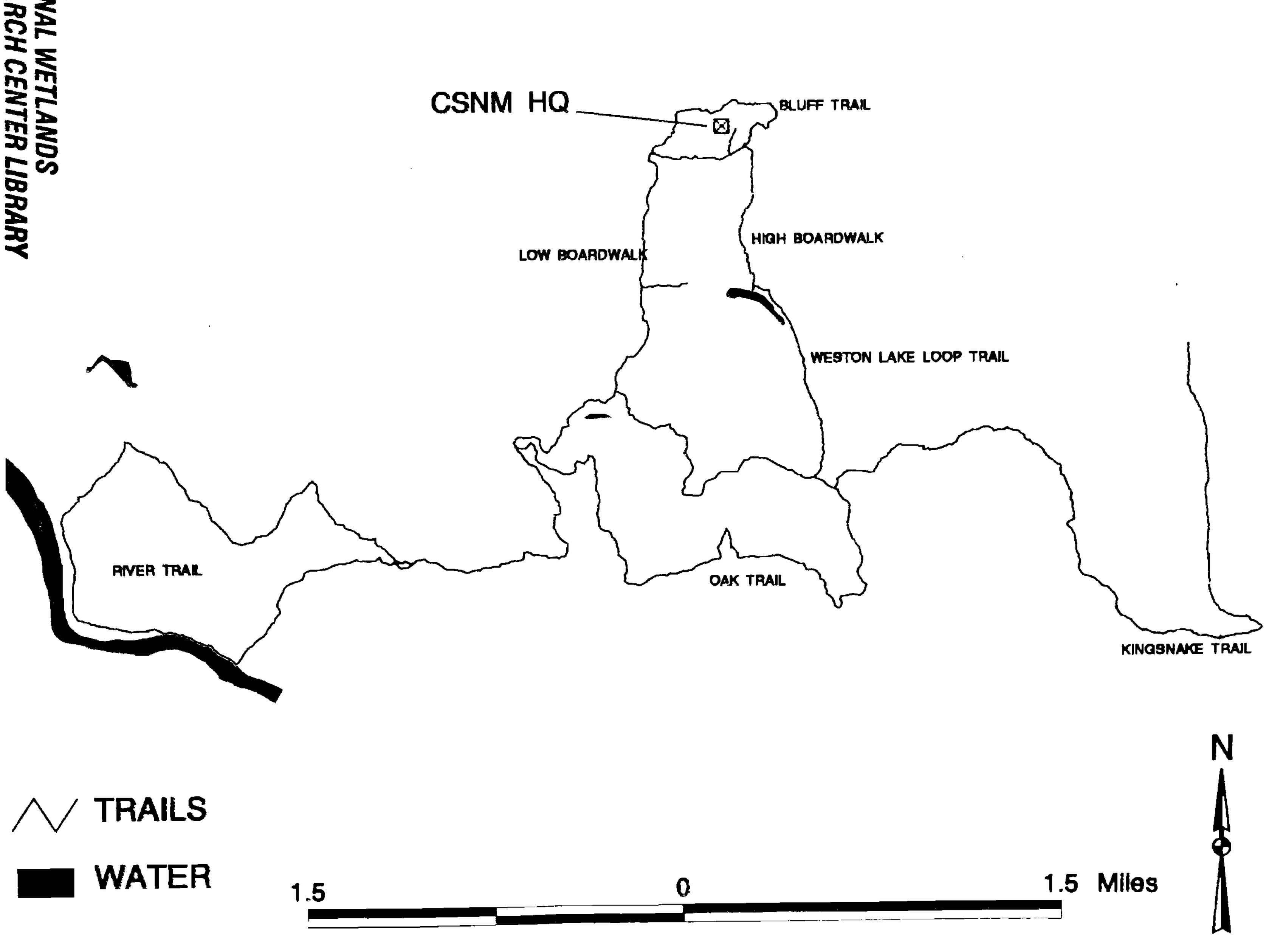


Figure 3.

TRAILS OF THE CSNM



Transects can be accurately planned and surveyed for the collection and monitoring of information associated with successional change and regrowth among vegetative communities using the trail system as a reference. The trail is located within 5 meters of its true position. GPS-assisted orientation can also be performed as research teams return to record trees for monitoring. Once the positions of individual trees are known, by obtaining a GPS coordinate for each tree, the coordinate can be entered into a GPS unit to locate the tree in question.

These GCPs were subsequently used to geometrically correct a digital SPOT multispectral satellite image dated March 26, 1989 for use as the base map for the entire database. This first step in database assembly reflects a change in methodology from the original concept of using scanned NAPP photo data as the base layer and subsequently rectifying them to the GCP network. The reason for this was that it proved unreliable to geometrically correct each of eight (8) pre- and 8 post-Hugo NAPP datasets and digitally mosaic them to form pre- and post-Hugo digital information layers.

Each original photograph is distorted differently and contains few identifiable GCPs that can be occupied on the ground for the collection of coordinates. Conversely, a single SPOT satellite image provides a geometrically uniform base across the entire Monument with minimal distortion related to curvature of a camera lens. The SPOT data are collected onboard a stable satellite platform approximately 500 miles above the earth's surface (Figure 4). These data are free from the tip, tilt, pitch and roll that are associated with aircraft and contain minimal photogrammetric distortion.

Additionally, the resolution or scale of the satellite imagery allowed ease of feature matching during subsequent co-registration with wetland related datasets to the GPS-rectified image base. The scanned air photo mosaic base introduced great difficulty in matching shared features from other datasets across different portions of the mosaic, derived from the different original photographs. This difficulty in matching features was found to be related to subtle differences in geometric correction of the different air photo datasets despite using the same overall set of GPS control points. The better resulting base layer upon which the rest of the database could be reliably built was found to be the single SPOT satellite image rectified to the single, complete set of 115 GPS-derived GCPs.

SPOT multispectral satellite image data containing 3 spectral bands or channels of information were acquired during the leaf-off period in early 1989 (Figure 4). The image was geometrically corrected or rectified using the network of GPS collected GCP positions. Conversion to UTM meter coordinates was then performed to remove distortion in the image data (20 by 20 meter pixels, or 0.1 acre each) related to curvature of the earth's surface, the planet's rotation on its axis and some terrain correction. These image data provide a digital basemap to which all other data layers are co-registered for close alignment of the datasets in the database.

National Aerial Photography Program (NAPP) color infrared photo transparencies acquired for pre- and post-Hurricane Hugo dates for late winter 1989 and 1991 were used for visual interpretation of the Congaree Swamp study site from an aerial perspective (Figures 5 and 6). The transparencies at the nominal scale of 1:40,000 were scanned into a digital format. Enlarged prints were acquired at scales of 1:24,000 (1" = 2000') and 1:4,800 (1" = 400') for underlaying with USGS topographic quadrangle data and identifying vegetative patterns.

Figure 4.

SPOT INFRARED IMAGE WITH CSNM BOUNDARY OVERLAY

Figure 5.

PRE HUGO SCANNED NAPP PHOTO

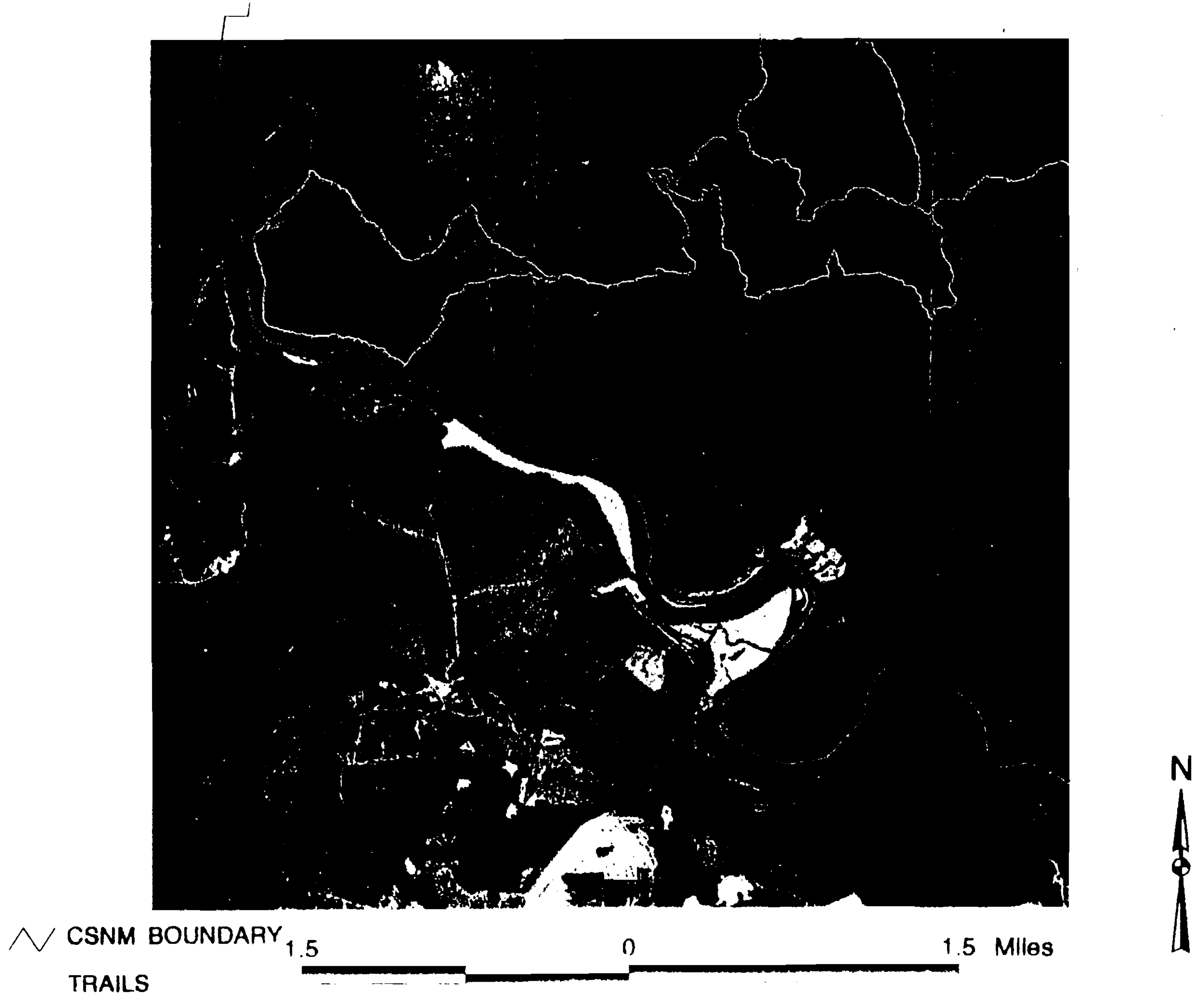


Figure 6.

POST HUGO SCANNED NAPP PHOTO

Digital scanning of the 1989 and 1991 NAPP transparencies was performed by Allen Cook, GIS/Remote Sensing Specialist, University of Georgia, Savannah River Ecology Laboratory (SREL). This resulted in the creation of 920 megabytes of color infrared photo image raster data at a spatial resolution of about 2 x 2 meters. These images were used in combination with other study site data layers. Pre-and post-Hugo NAPP internegatives were also scanned and mosaics were produced digitally by HAS Images, Inc., Dayton, Ohio, for improved change detection datasets (Figures 5 and 6).

Although the pre- and post-Hurricane Hugo scanned NAPP mosaic datasets were rectified to the set of 115 GCPs, the digital photo mosaic data were not used. The NAPP mosaic datasets could not be used as the geocontrol or base dataset because it was impossible to process these data into discrete vegetative community types. Combining the NAPP data with other datasets for comparison and partial delineation of vegetative community patterns did not improve the ability to accurately classify or segregate vegetative community types. Therefore, project components #6, #7 and #12 (see pages 8 and 9) were not accomplished as written. Instead, testing of pattern recognition techniques and selective data layer interpretation was performed. This method yielded positive results which include the delineation of near-monospecific stands of swamp tupelo within the Monument, by using Dorovan Muck mapping units from the NRCS soil survey data, and wetland vegetation categories from unsupervised classes of SPOT data that approximate cypress/tupelo swamp sloughs.

Mapped contour lines, elevation points and hydrographic features provided by a 1985 USGS report by Patterson et al. were digitized and co-registered with the rectified digital SPOT image data (Figures 7 and 8). These data were best-fit for production of detailed topography (4-foot contour intervals) and surface hydrologic feature layers that delineate former Congaree River meanders, oxbow lakes, sloughs, creek bottoms and potential wetland areas. Only every other 2-foot contour line in the original data was digitized. The 2-foot data were impossible to trace without risking confusion of mapped lines, particularly in areas with steep slopes along bluffs overhanging the river channel. The resulting 4-foot contour dataset contained sufficient detail for determination of vegetative patterns related to elevation differences which, together with surface hydrologic features, indicate close correspondence with NWI wetland polygons, some soil types, the original Smathers (1980) vegetative community map, and an aggregated version of the Smathers map.

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The NWI maps for the Gadsden and Wateree, South Carolina, 7.5-minute topographic quadrangles were digitized, best-fit to the rectified satellite image base, edge-matched and co-registered to the other data layers (Figure 9). These NWI classes were aggregated (275 to 18) according to a position paper (September, 1988) prepared by John M. Hefner, Regional Wetlands Coordinator with the National Wetlands Inventory regional office in Atlanta for the South Carolina Distribution Center of USFWS/NWI information located at the USGS ESIC affiliate office in Columbia, South Carolina (Appendix B). Close correspondence was observed between NWI polygons representing PFO1/2 (cypress/tupelo swamp forest) and land cover categories derived from unsupervised classification that resulted from the discrimination of soil wetness characteristics and hydrophytic vegetation detected in the remotely sensed data. This was particularly apparent along the central portions of the Swamp sloughs associated with former oxbow features. NWI wetlands were aggregated to produce a picture of total wetlands for the Monument (Figure 10).

Figure 7.

4 FOOT ELEVATION CONTOURS

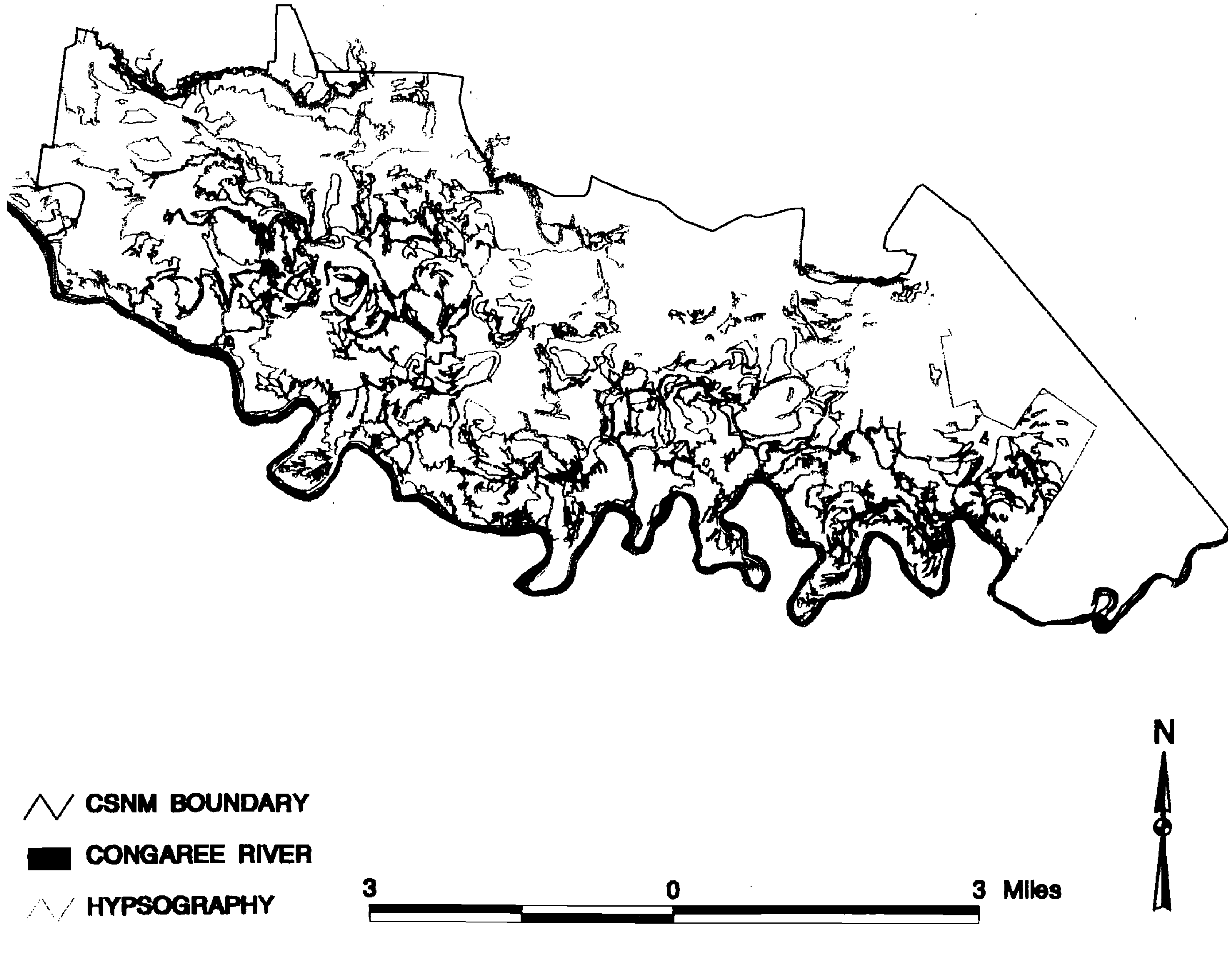


Figure 8.

MAJOR LAKES & STREAMS

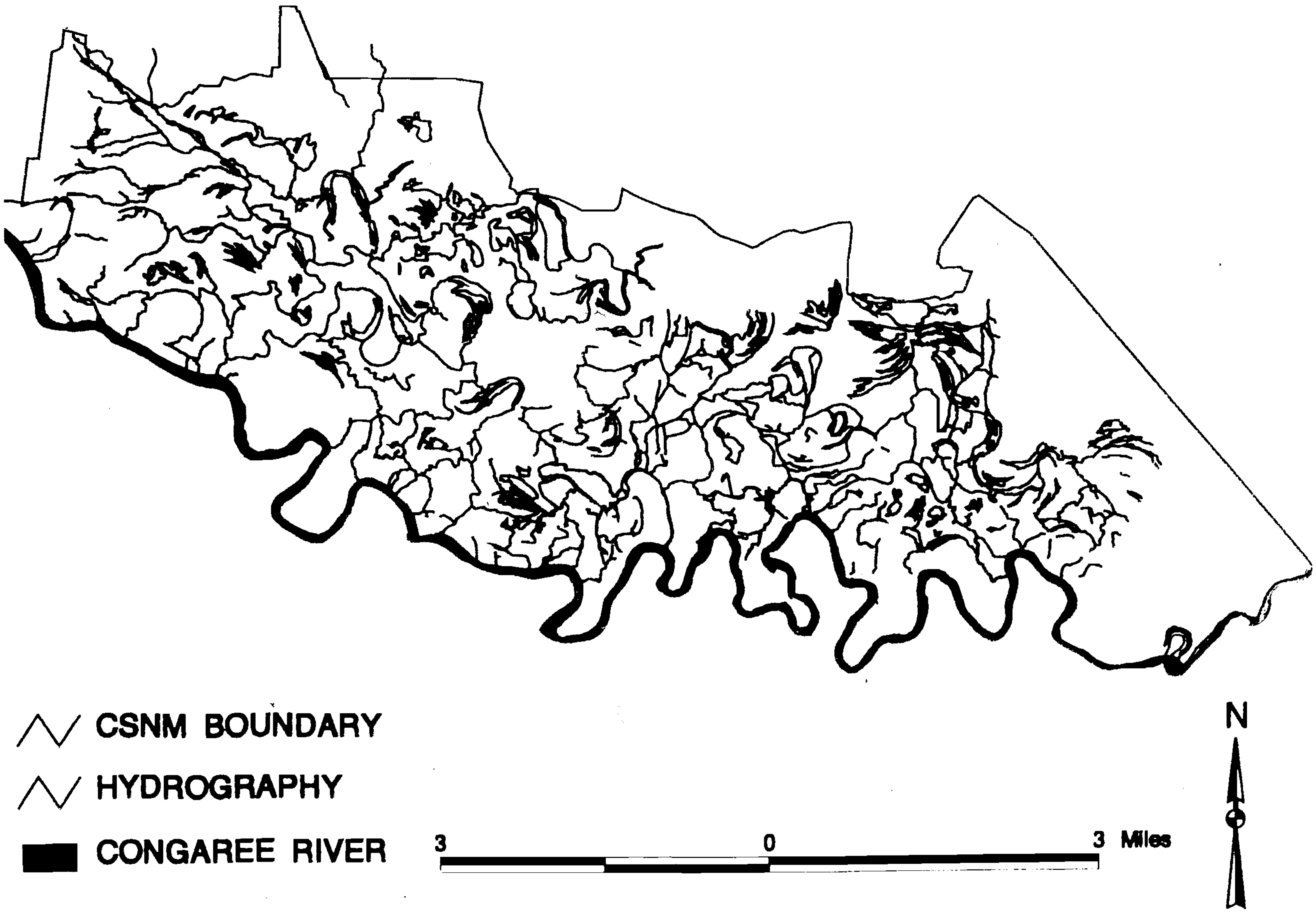


Figure 9.

AGGREGATED NWI WETLANDS

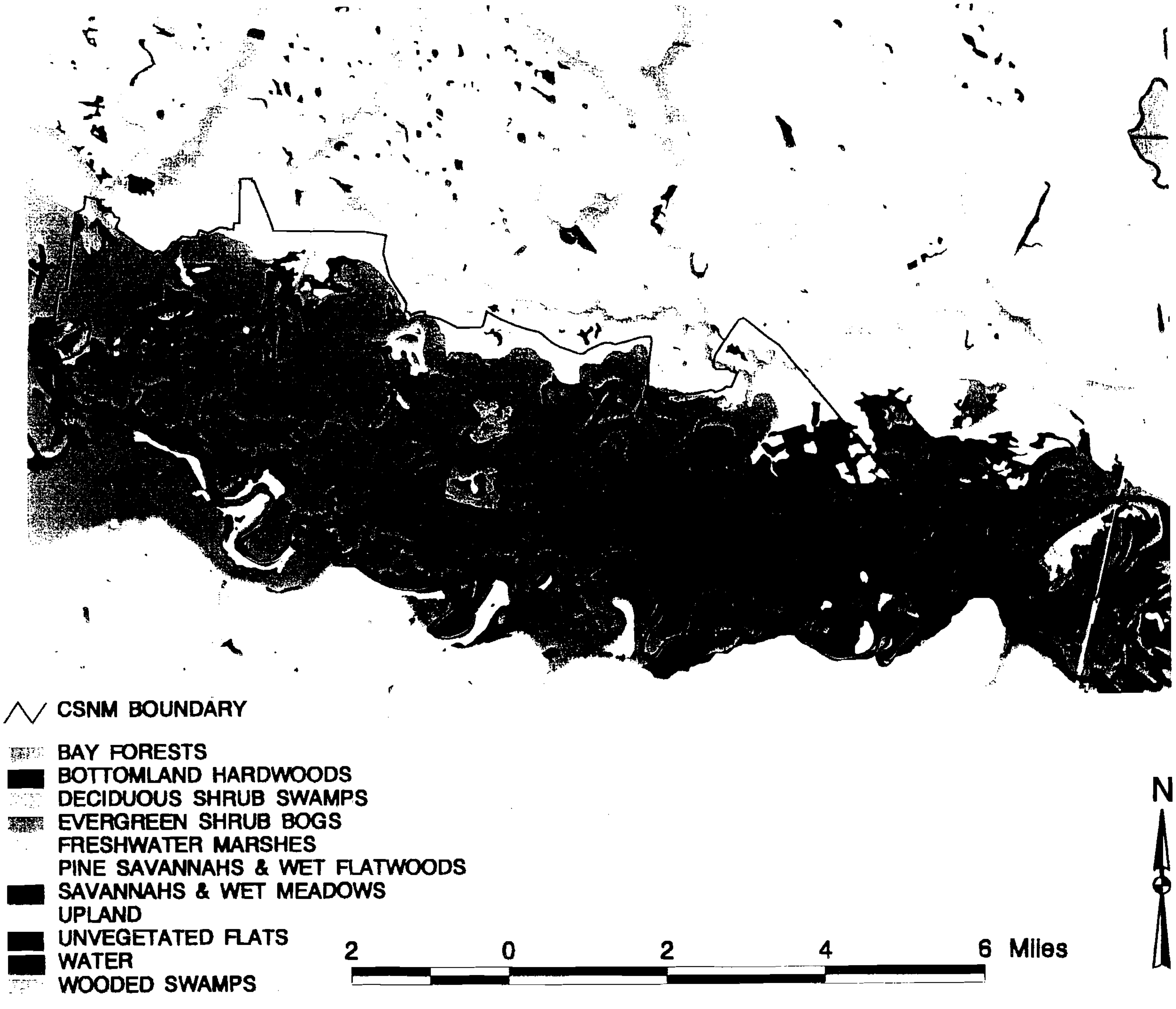
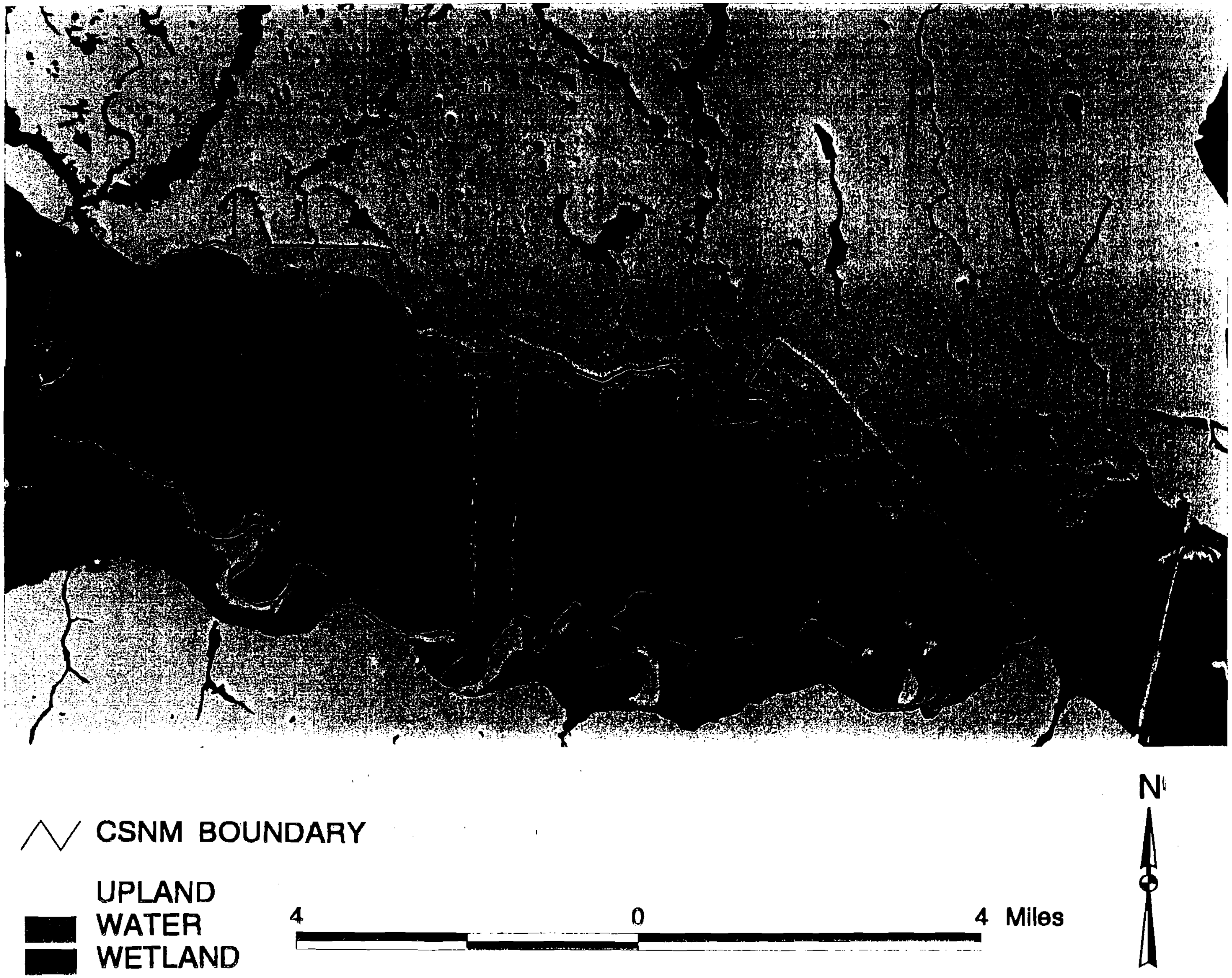


Figure 10.
NWI WETLANDS



The USDA Natural Resource Conservation Service (NRCS) Richland County soil survey mapping units were digitized from individual map sheets, co-registered to the GCP-based satellite image dataset and digitally stitched together into a seamless data layer (Figure 11). This dataset, which included soil mapping units designated as hydric, was used in combination with other information layers for an evaluation of common intra-dataset pattern correspondence and relationship. The soil survey data were aggregated to produce two separate hydric soil groupings; one group contains hydric soils throughout the mapping unit while the other group contains hydric soils as an inclusion to the soil mapping unit (Figure 12).

The 1980 Smathers vegetative community map, based on 1976 black-and-white aerial photography, was digitized and best-fit to the image base for comparison between vegetation patterns and those of the NWI, soils, hydrology and elevation data layers (Figure 13). The vegetative categories in this dataset were also aggregated to create combined community associations for greater correspondence to other data layers. This vegetation aggregation was mainly performed for comparison to satellite image based land cover datasets with classes delineating a combination of wetland vegetative communities of like hydrologic regime and elevation.

The SPOT satellite image for the Monument and immediate surroundings was GCP-rectified and classified to produce a general land cover/land use dataset for the Monument and environs (Figure 14). Landsat Thematic Mapper (TM) imagery was also processed to identify vegetative community patterns across the Monument for comparison to the detailed 1980 Smathers vegetation map and aggregated vegetative data.

The USGS digital line graph (DLG) basemap data were assembled into a uniform dataset by GCP-rectification, edge-matching and incorporation into the Monument database for overlay onto other information layers. This provided additional infrastructure and hydrology information for further detection of patterns and comparison with other datasets.

Forest dynamics study plot boundaries were incorporated into the Monument database via GPS-acquired UTM point coordinates established by Savannah River Ecology Laboratory scientists. These study plot boundaries can be used for reference in all future investigations.

GPS-derived locations of champion or near-record trees will be incorporated into the database upon completion of project work conducted by Dr. Bob Jones of Virginia Tech. Further GPS-acquired locational data for any features of interest on Monument property can easily be included in this digital baseline of information since the precision associated with most standard GPS units is greater than or equal to 5 meters after differential correction.

The public education module was designed to include a standardized demonstration of the Monument's database with a zoom-in look at various Swamp features as well as its location within the State of South Carolina with respect to river systems, watershed basins, major population centers and road networks. The module operator is also able to select other options to further investigate characteristics of the Monument. Detailed instructions on the operation of this module are included as an appendix to this report.

Figure 11.

CSNM SOILS

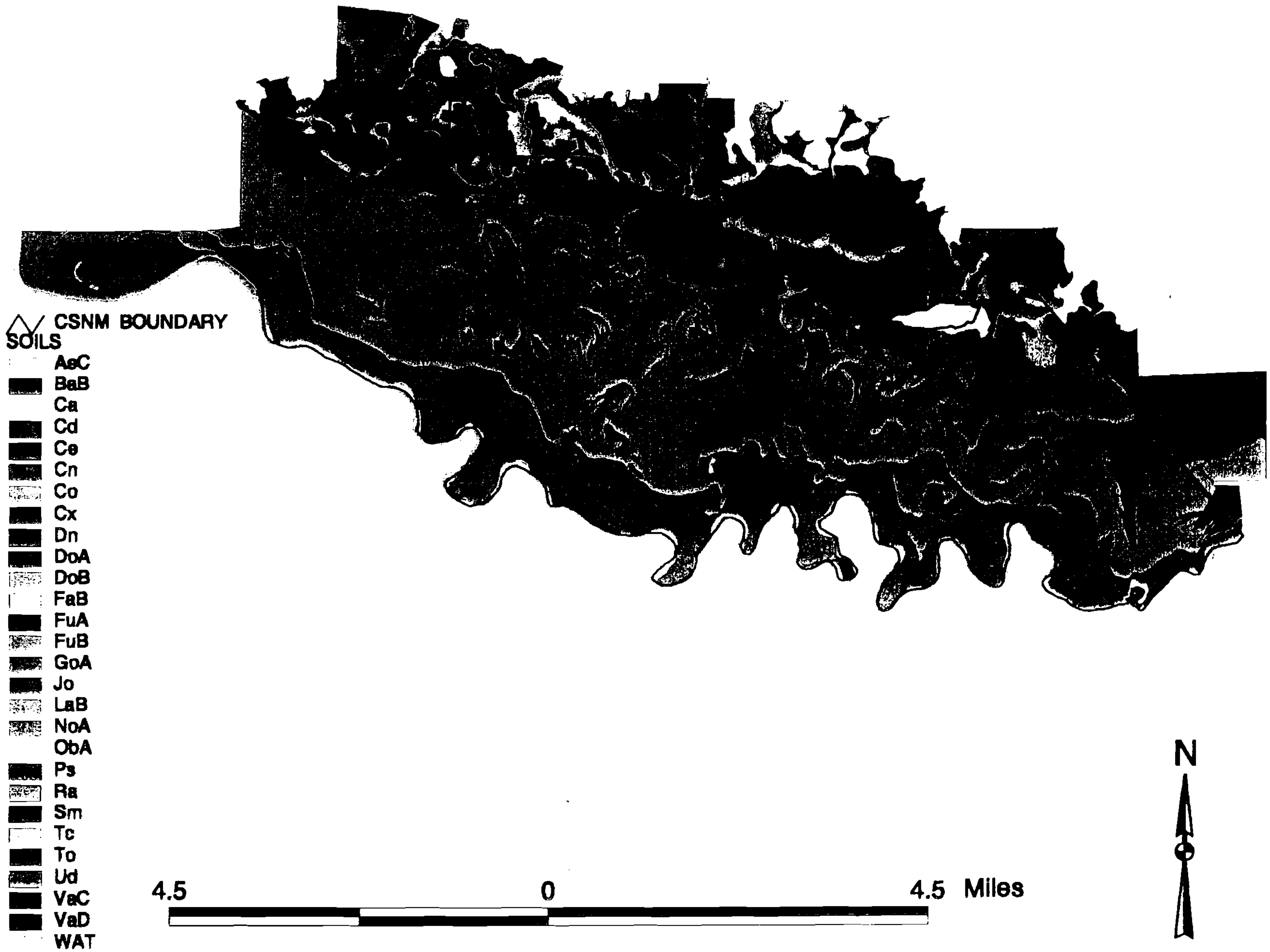


Figure 12.

HYDRIC SOILS

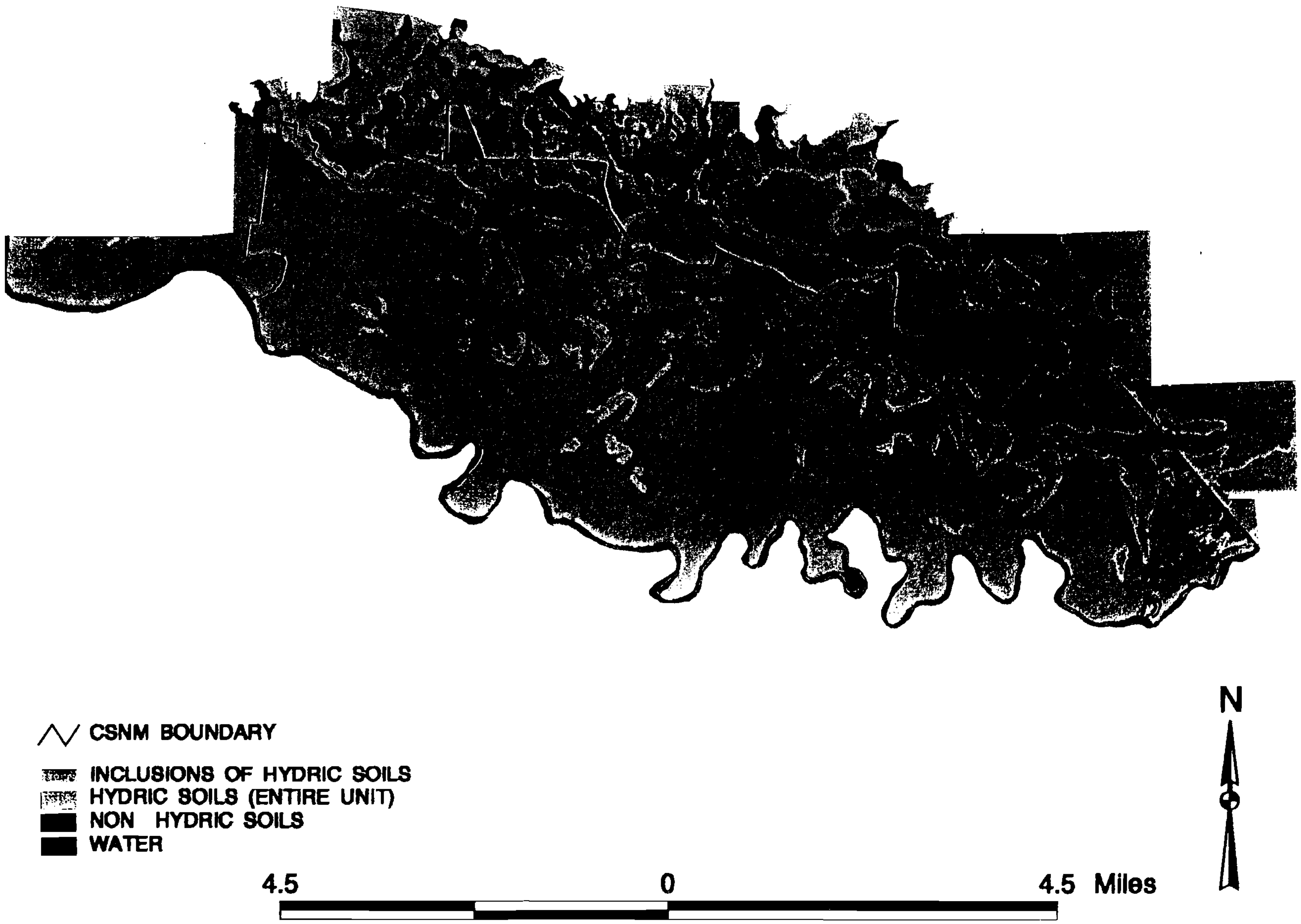
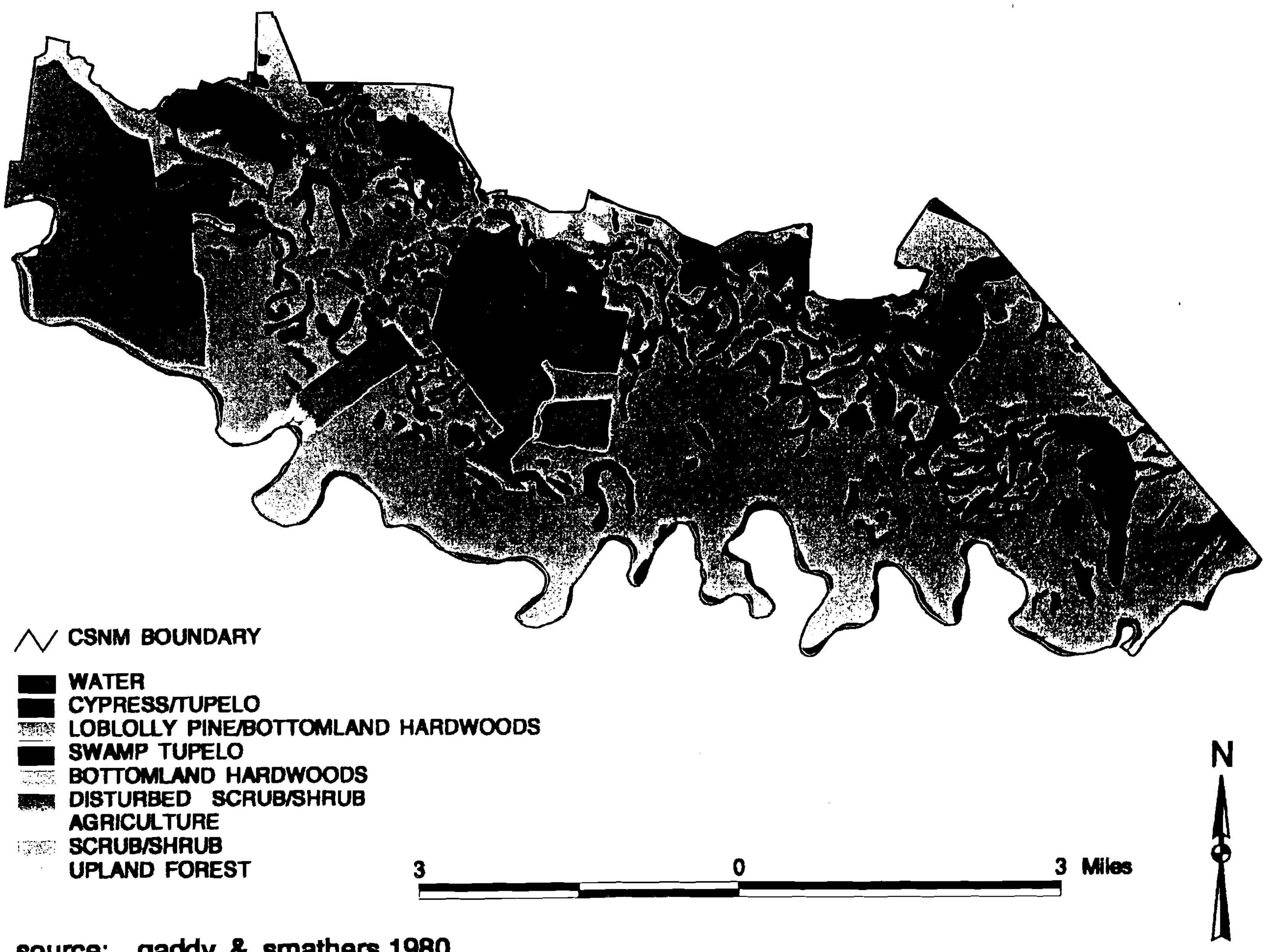


Figure 13.

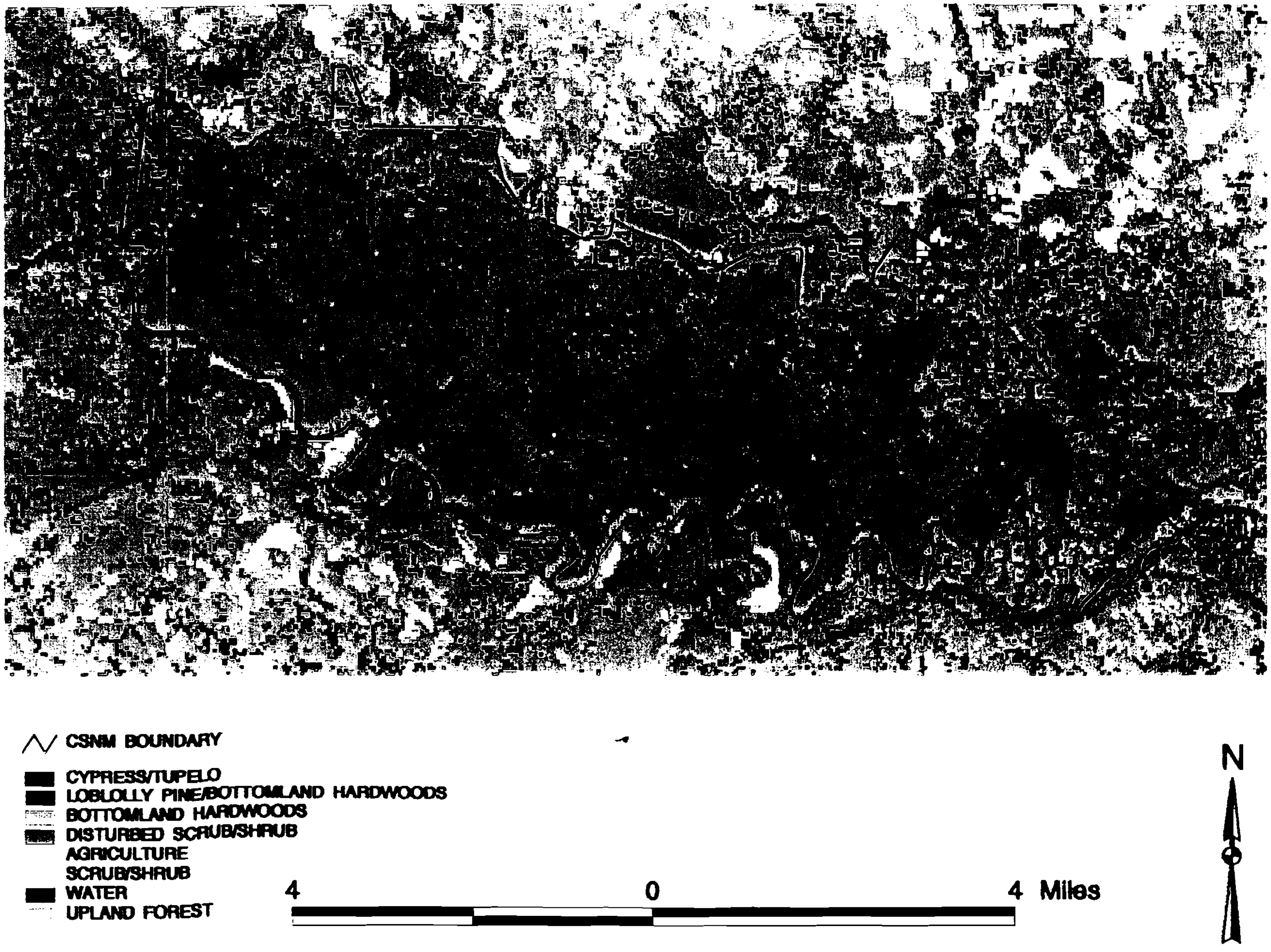
VEGETATION TYPES



source: gaddy & smathers,1980

Figure 14.

UNSUPERVISED CLASSIFICATION OF SPOT IMAGE



The analysis of biomass gaps, blowdowns and vegetative shadow areas resulting from Hurricane Hugo by change detection between pre- and post-Hugo scanned NAPP mosaics was limited due to the limited photo resolution quality of the scanned data. Specific patterns of storm damage were difficult to detect due to the 20,000-foot aircraft altitude specified by the NAPP. Background soil moisture and standing water introduced confusion into the spectral signatures sensed by the color infrared film and modified the visual effects of disturbances from an aerial perspective.

It proved impossible to differentiate between general "broad-brushstroke" patterns of disturbed trees and the natural "disturbed" look of the complex Swamp forest with its subtle variations in elevation, surface hydrologic features and vegetative composition (Figure 15). To accomplish the analysis of Hurricane Hugo biomass gaps, blowdowns and vegetative shadow areas, lower altitude aerial photographs are required producing far greater clarity of the ground for successful discrimination of storm affected surface features. Ideally, this aerial photography is acquired during non-flooded periods to optimize photo interpretability.

Ground truthing of the NAPP air photo and SPOT and TM satellite image data was minimal due to both the amount of time required to georeference the data layers to the GPS rectified SPOT satellite image base and lack of specifically identifiable vegetative communities in the photography and imagery. Different wetland vegetative communities often have similar visual characteristics from a vertical perspective.

Such survey work would be best based on low-altitude, high-resolution color infrared photography or aircraft-borne, hyper-spectral imagery for accurate correlation to ground transect surveys, producing superior ground truth. Hyper-spectral images can be acquired from low-altitude aircraft platform that contain a large number of spectral bands or information channels. Such imagery provides subtle differences in spectral response f surface features.

Results

Major results of this project are twofold: (1) a digital database composed of several remotely sensed data layers, digitized mapped information and GPS-acquired elements assembled in a GIS for the Congaree Swamp National Monument and (2) a wetland resource characterization derived from several data layers compared to better describe vegetative communities. Products prepared for the Service are listed in Table 1 and data for the Monument built into the GIS are listed in Table 2.

Table 1. PRODUCTS PREPARED FOR THE NATIONAL PARK SERVICE

NAPP 1:40,000 scale transparencies (pre-/post-Hurricane Hugo)
NAPP 1:24,000 print enlargements (pre-/post-Hurricane Hugo)
NAPP photo mosaic enlargements (pre-/post-Hurricane Hugo)
NAPP scanned digital data - 2 sets (pre-/post-Hurricane Hugo)
TRIMBLE Global Positioning System (GPS) equipment unit
ERDAS-derived ARC/INFO image-based GIS database
Public Education Module/Database Operations Manual

Figure 15.

csnm subset

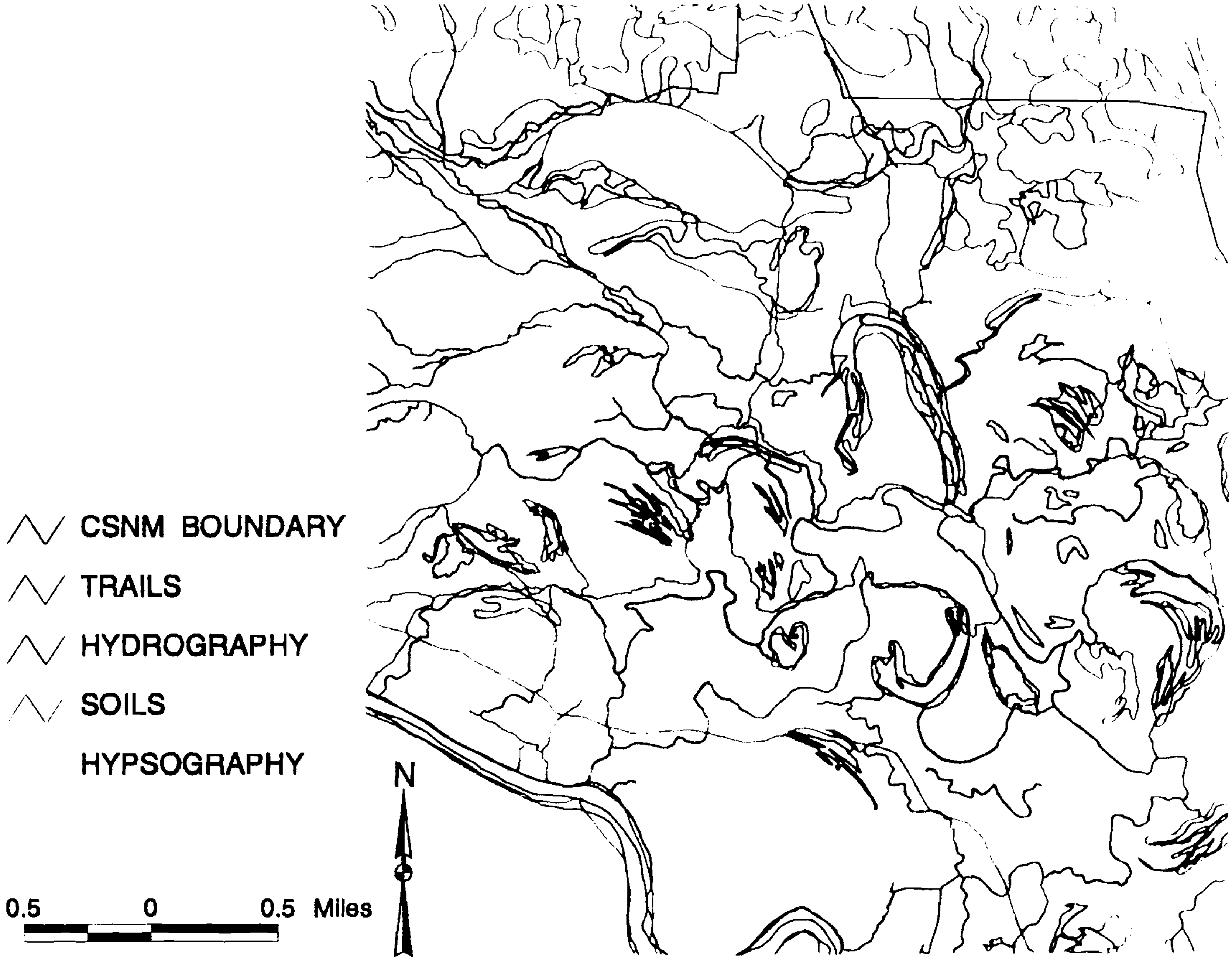


Table 2. LAYERS ASSEMBLED FOR MONUMENT GIS DATABASE

Data Layer	Source (Date)	Capture Method
Legal Monument Boundary	USDOI/NPS (1994)	Digitizing
Ground Control Points	SCDNR (1992-94)	GPS
Survey Monuments	USGS/SCDOT (1976-88)	Digitized
SPOT Satellite Imagery	SCDNR/SPOT (1988-90)	Digital
Landsat TM Imagery	SCDNR/EOSAT (1990-92)	Digital
Pre-Hugo NAPP Photo(1)	SCDNR/SREL/USGS (1989)	Scanning
Post-Hugo NAPP Photo(1)	SCDNR/SREL/USGS (1991)	Scanning
Pre-Hugo NAPP Photo(2)	SCDNR/HAS/USGS (1989)	Scanning
Post-Hugo NAPP Photo(2)	SCDNR/HAS/USGS (1991)	Scanning
Elevation (contours)	USGS/WRD (1985)	Digitizing
Surface Hydrology	USGS/WRD (1985)	Digitizing
Soil Types	USDA/NRCS (1978)	Digitizing
NWI Wetland Types	USFWS/NWI (1983)	Digitizing
Vegetation Types	Smathers/Gaddy (1976)	Digitizing
Land Cover/Land Use	SCDNR/SPOT (1988-92)	Digital
Land Cover/Land Use	SCDNR/EOSAT (1990-92)	Digital
Digital Line Graph	USGS/SCDNR (1983)	Digitized
Park Trails/Boardwalks	SCDNR (1992-94)	GPS
Points of Interest	SCDNR (1992-92)	GPS
Forest Dynamics Plots	SREL (1990-93)	GPS
Record Trees	Auburn Univ. (1995)	GPS

Notes: "Digitizing" - SCDNR personnel digitized existing data.
"Digitized" - Data already digitized by other personnel.
"Digital" - Data already acquired in digital format on tape.
"Scanning" - Data scanned as part of this project.
"GPS" - Data collected using GPS equipment by source.

Wetland Resource Characterization

Generally, the Monument's legally authorized boundary was used to "cookie-cut" or extract the other datasets from larger data coverages. The color infrared SPOT multispectral image (bands 1/2/3: green/red/near infrared) was georectified to the network of 115 GPS-acquired ground control points (GCP). All other data layers were co-registered to the image base. For each additional dataset, "blocks" or rectangular portions of data were co-registered to the image base, block by block, until a precise overlay was achieved over the entire dataset. In this way, all datasets were brought into relatively accurate position with all other datasets for optimal geographical uniformity among data layers.

Certain datasets, notably the surface hydrologic and topographic information from the USGS paper blueline map, required intensive co-registration to the image base due to shrinkage of the paper map and uncertain horizontal control of the original map survey. In an iterative process to geometrically correct the data, digital "rubber sheet stretching" techniques based on photogrammetric principles were applied to these datasets. Eventually, after rigorous digital processing, a reasonable degree of success was achieved, producing datasets which corresponded closely to the base dataset across the majority of coverages. Occasional portions of datasets are not perfectly aligned with the SPOT image base or with each other; however, planimetric discrepancies are minimal overall, reflecting a best possible fit of the data.

SPOT and TM image datasets provide a uniform color infrared (false color composite) appearance of the Monument which shows general patterns reflecting the complex geomorphic nature of the Swamp system. These image datasets form base layers upon which it is useful to build multiple data combinations to describe vegetative and hydrologic conditions in the Swamp. As a "backdrop" layer, the image data allow for comparison of corresponding wetland polygons, or digital areas, on the NWI, Smathers vegetation, soil survey, surface hydrology and elevation datasets.

For example, subtle variations in the distribution of polygons representing different wetland resources for the Weston Lake oxbow slough system indicate remarkable consistency between data layers in the bald cypress/water tupelo community. This community forms a concave-southward area. Weston Lake forms an arcuate oxbow water body of wooded swamp sloughs extending to the south on the east and west sides of the lake, marking the former position of the Congaree River meandering across the floodplain. Most of these wetland oriented datasets show the edges of the slough system to be within 100 feet of each other due to the various planimetric bases of the source datasets. Having homogeneous canopies, these slough cypress and tupelo trees occur as dominant species within certain microelevational environments associated with certain surface hydrologic features, and were easily identified through air photo interpretation by NWI biologists. By closer comparison between groups of pixel brightness values to one of the wetland oriented datasets, the image base often serves to clarify mapping of a wetland vegetative community.

Total wetlands within the Monument were measured according to three (3) datasets: (1) NWI data, (2) soil survey data, and (3) Gaddy/Smathers (1980) vegetation data. The USFWS NWI wetlands, based primarily on hydrophytic vegetation canopy visible in early 1980's National High Altitude Photography (NHAP), amounted to approximately 20,269 acres, or 91.3% of the Monument site. The USDA/NRCS Richland County soil survey mapping units amounted to approximately 14,785.2 acres (66.6%) soils hydric throughout, 6,460.2 acres (29.1%) soils hydric within inclusions only, or a total of 21,245.4 acres (95.7%) with either type of hydric soils. The Gaddy/Smathers vegetation map indicated approximately 15,940 acres (71.8%) of unaltered wetlands, excluding selectively and clear cut lands which may, in part, occur within wetland portions of the Swamp.

Remarkable correspondence occurs between Dorovan Muck soils and Swamp Tupelo stands throughout the Swamp (Figures 16 and 17). This can, in part, be explained by the fact that soil scientists and field mappers tend to use vegetation boundaries as soil mapping unit boundaries whenever feasible. It is logical that these vegetative communities are coincidental to homogeneous soil types. The second- to-the-far-west, well-correlated area of swamp tupelo and Dorovan Muck serves as evidence of good overall correspondence in geographic distribution of these two resources.

Figure 16.

DOROVAN MUCK / SWAMP TUPELO CORRELATION