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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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

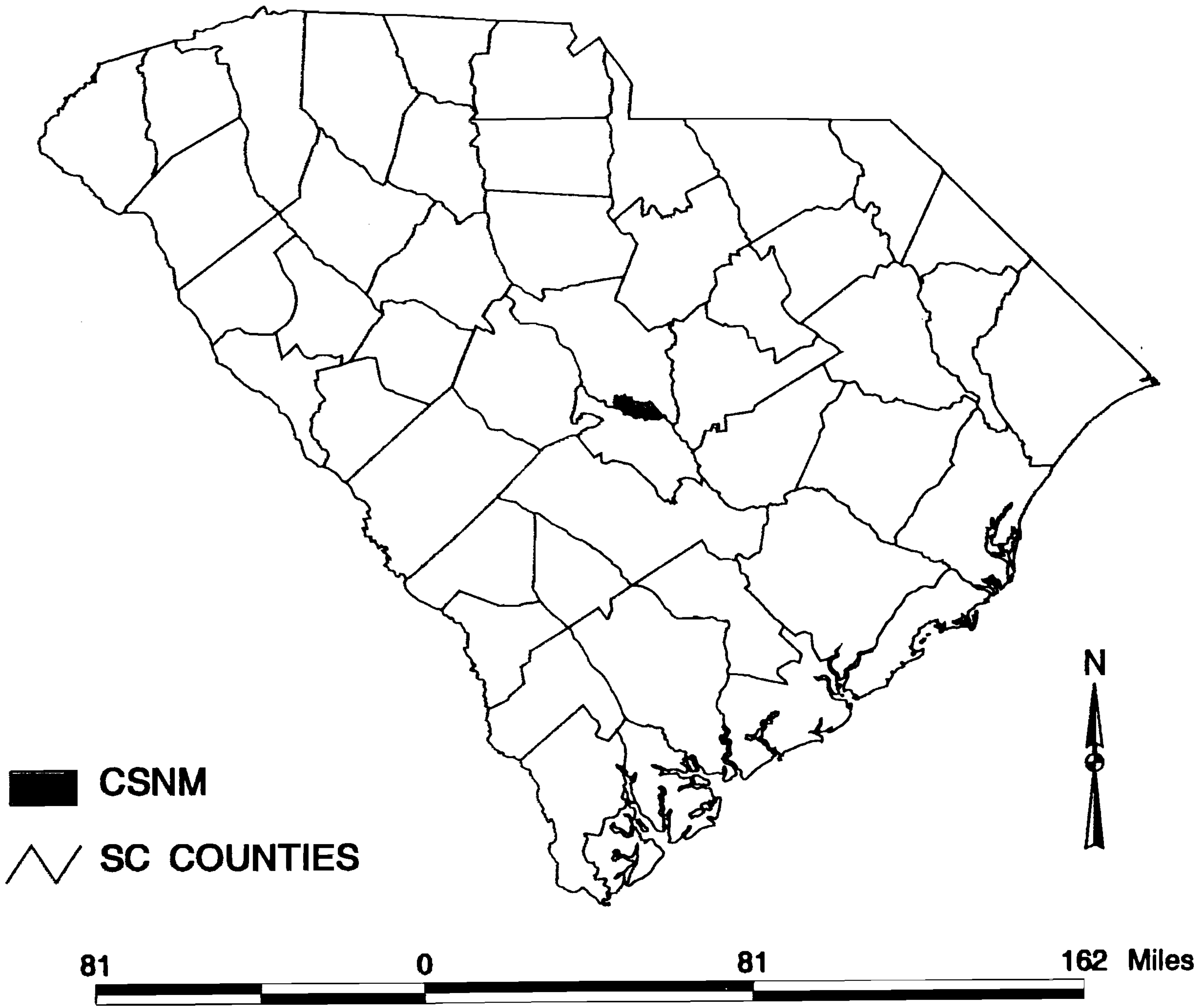


Figure 2.

CSNM BOUNDARY & TRAILS & GCPS

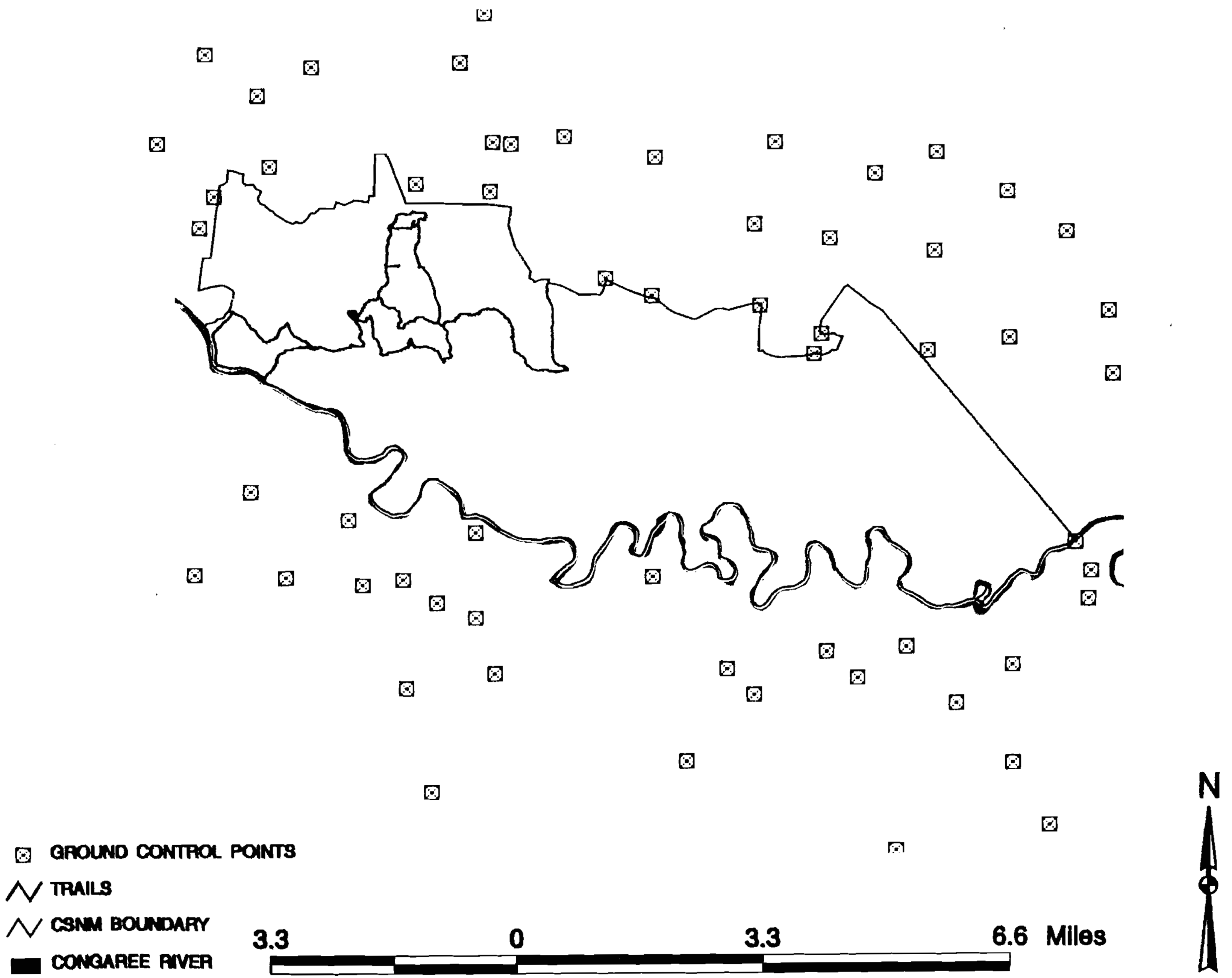
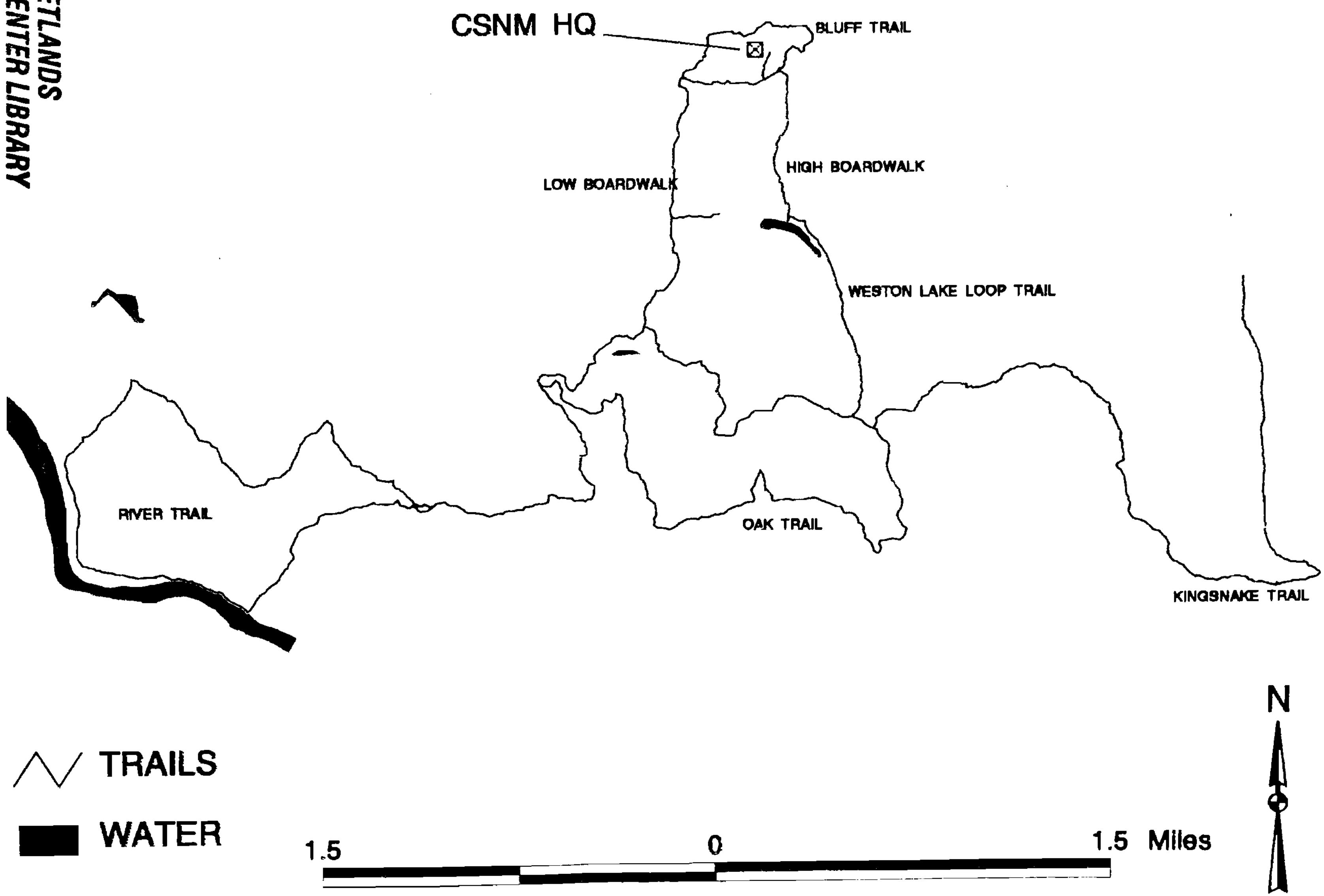


Figure 3.

TRAILS OF THE CSNM

NATIONAL WETLANDS
RESEARCH CENTER LIBRARY
700 Cajundome Blvd.
Lafayette, LA 70506-3152



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

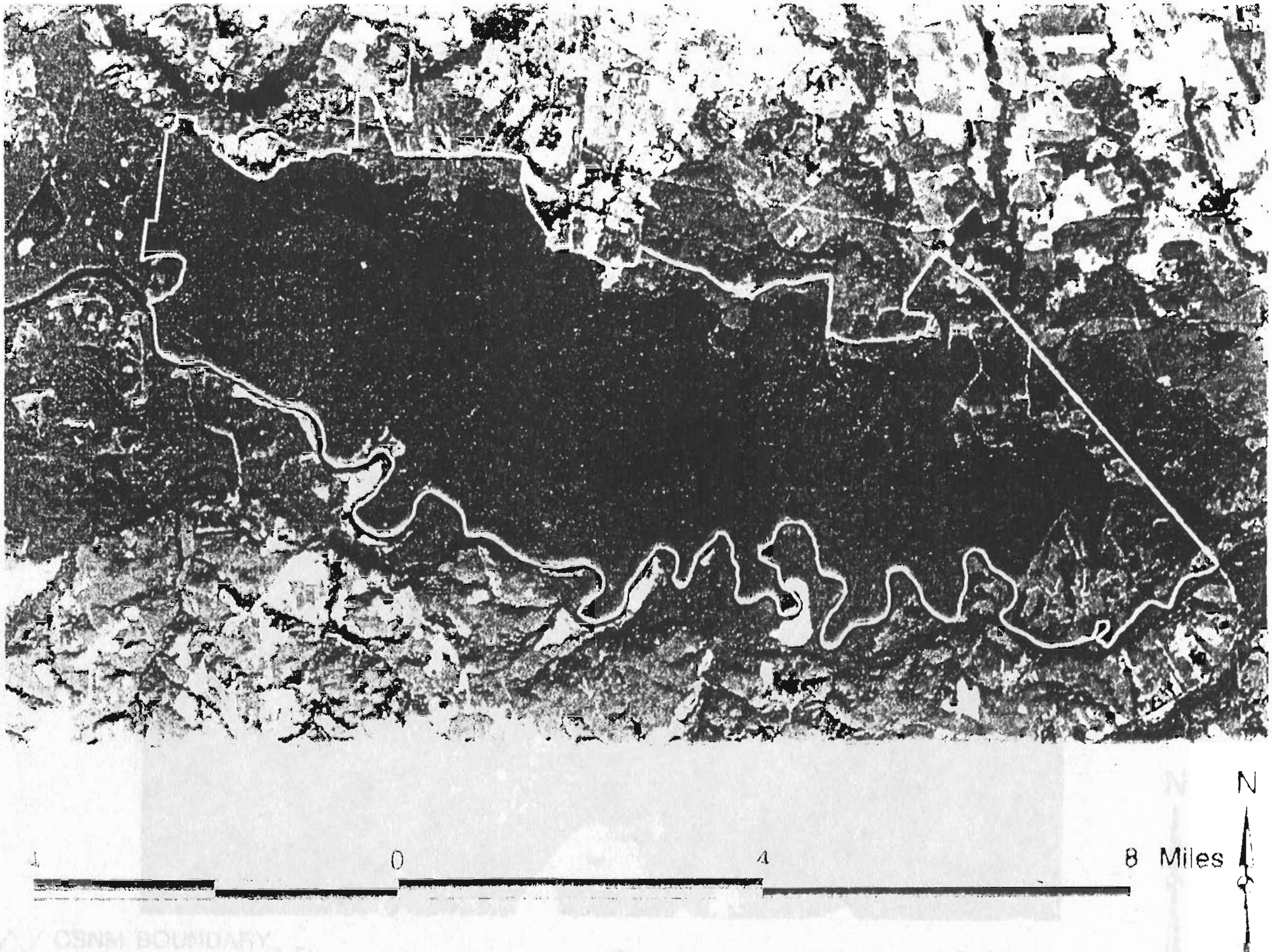


Figure 5.

PRE HUGO SCANNED NAPP PHOTO

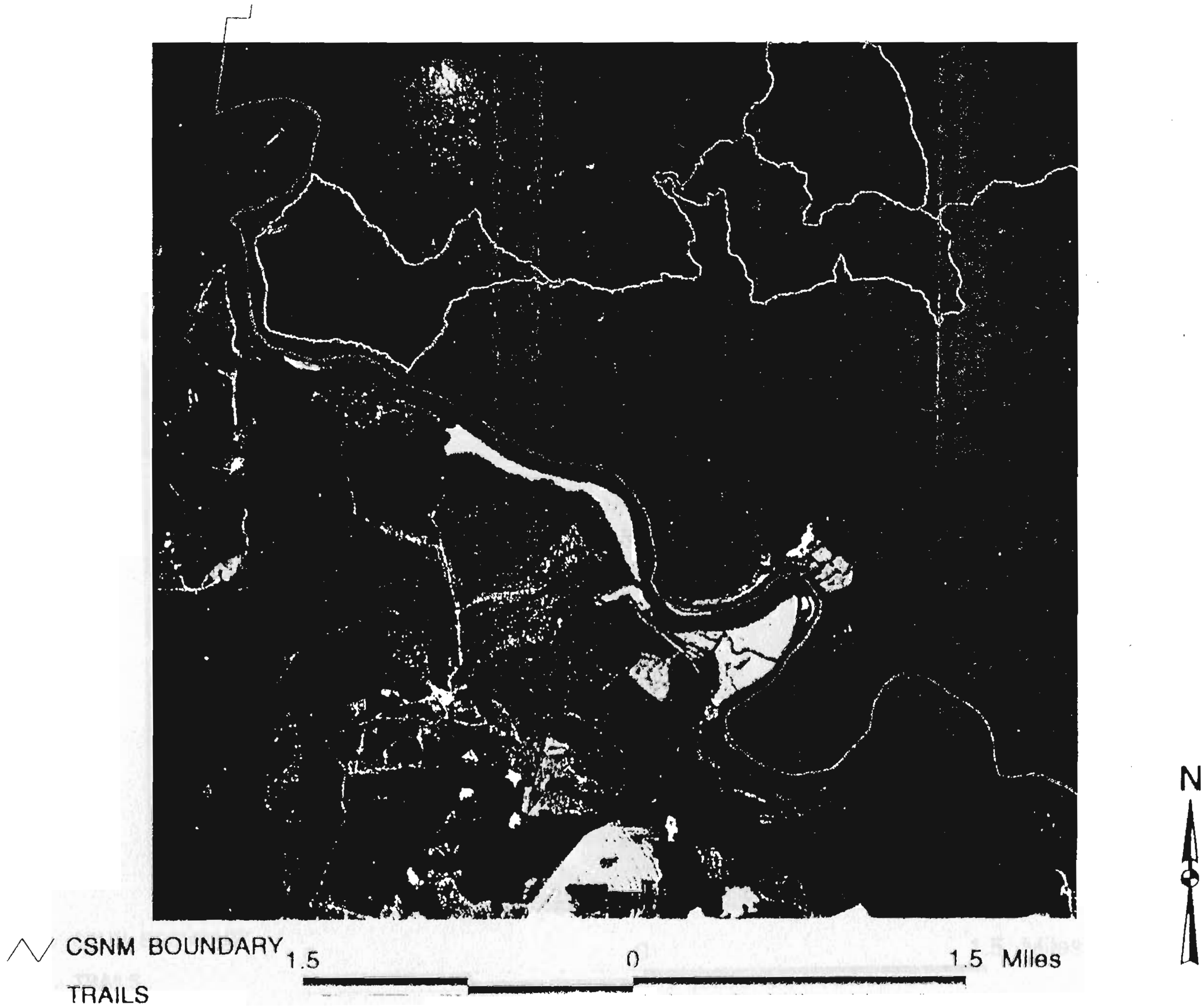
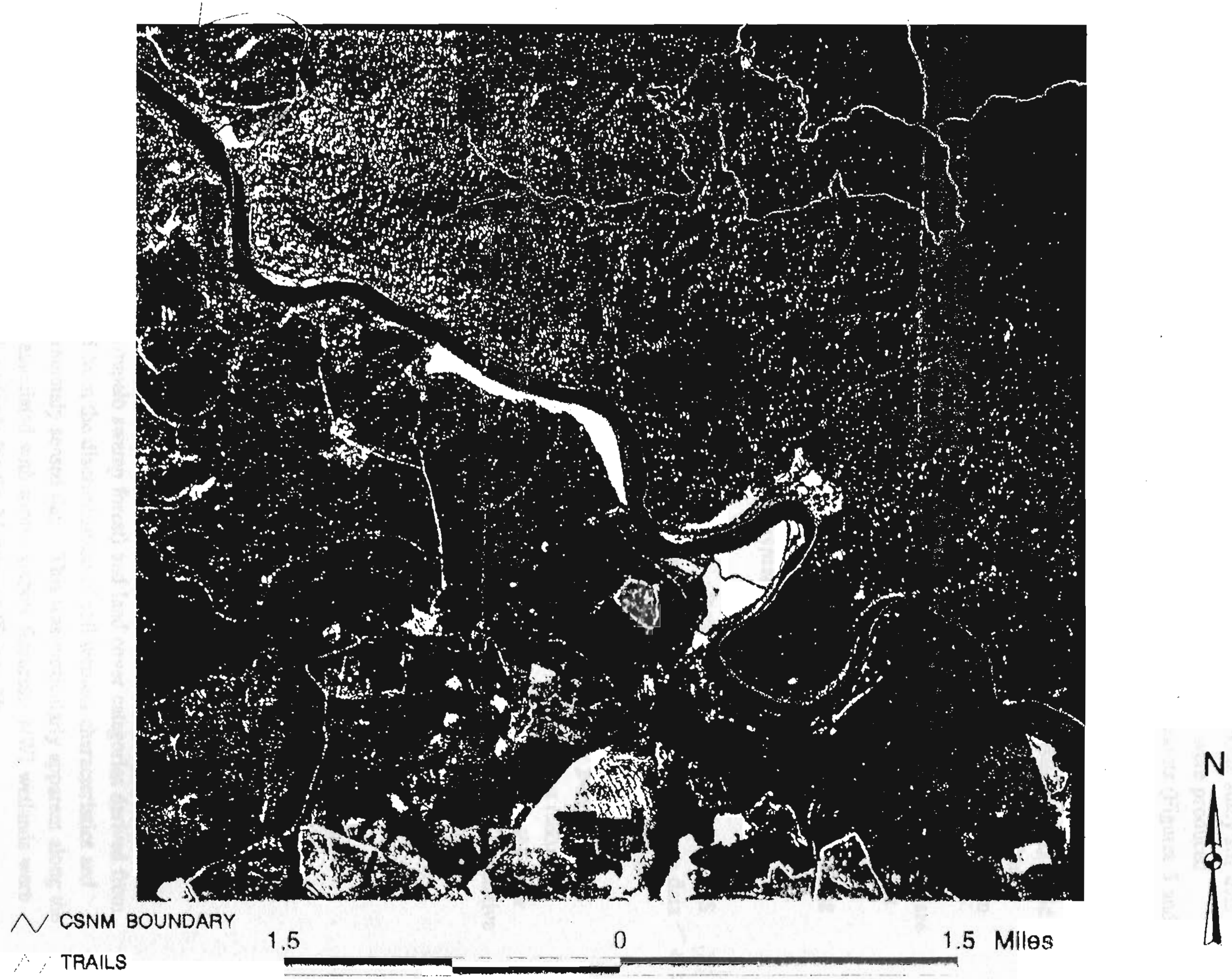


Figure 6.

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.

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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.

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

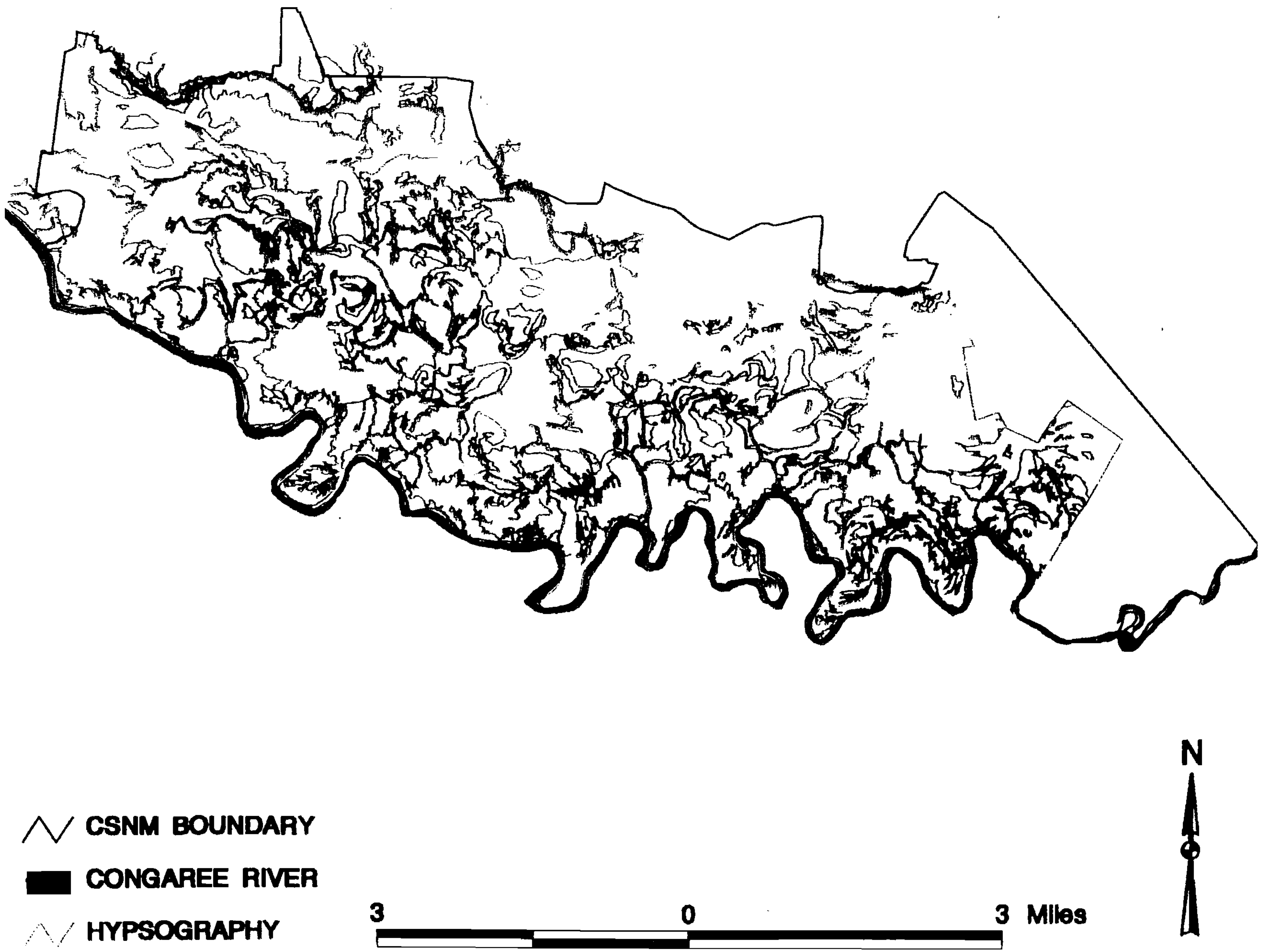


Figure 8.

MAJOR LAKES & STREAMS

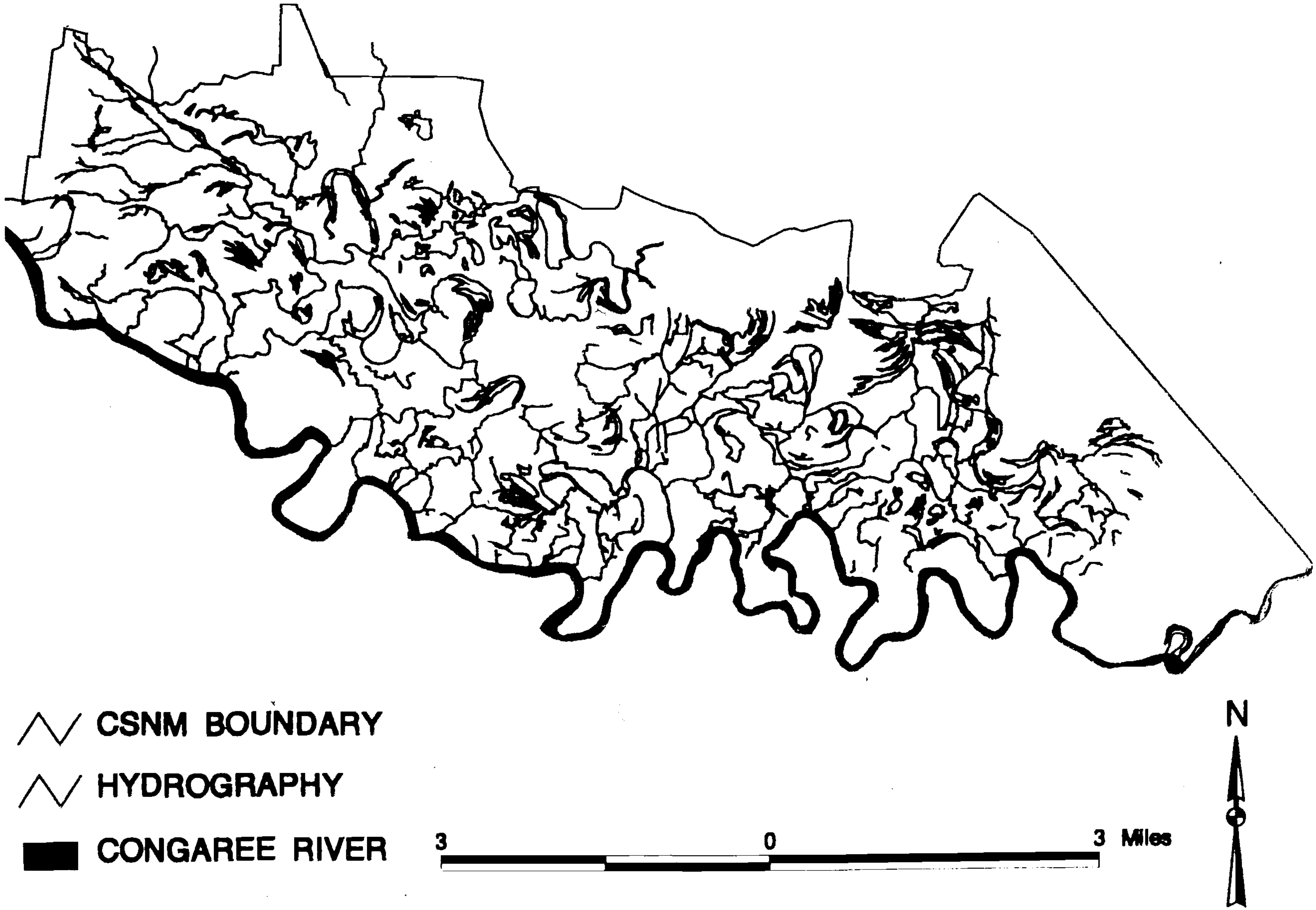


Figure 9.

AGGREGATED NWI WETLANDS

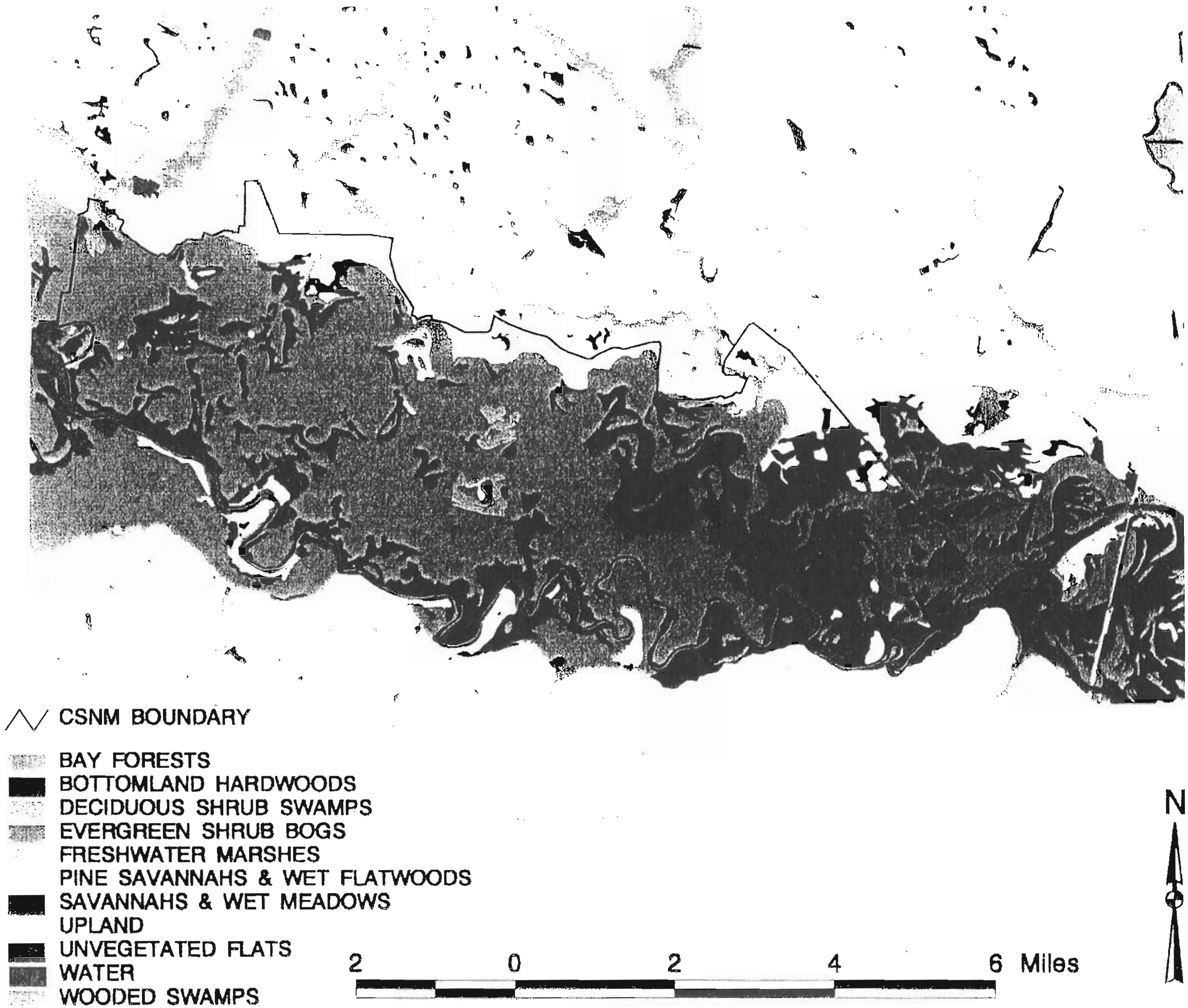
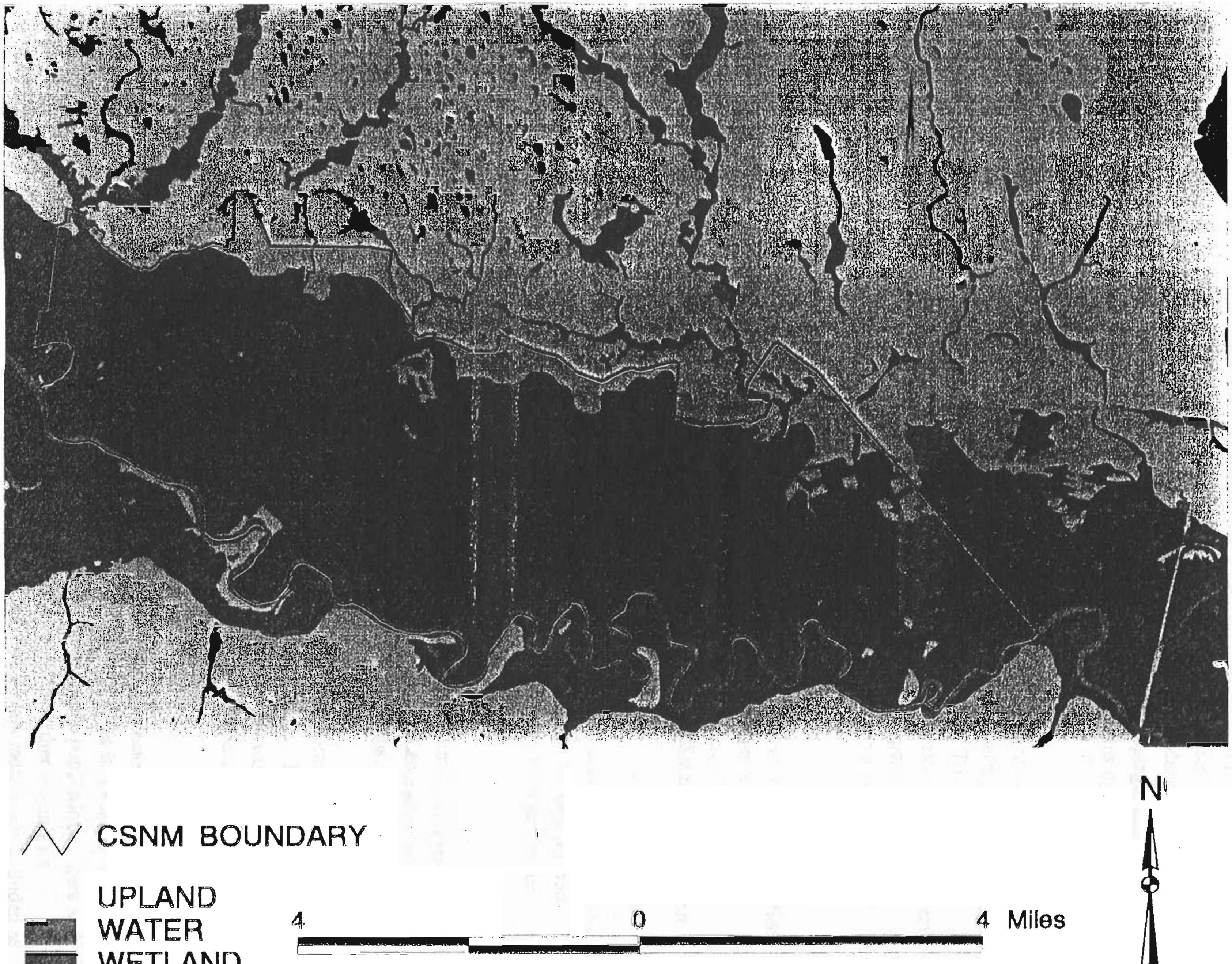


Figure 10.
NWI WETLANDS



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

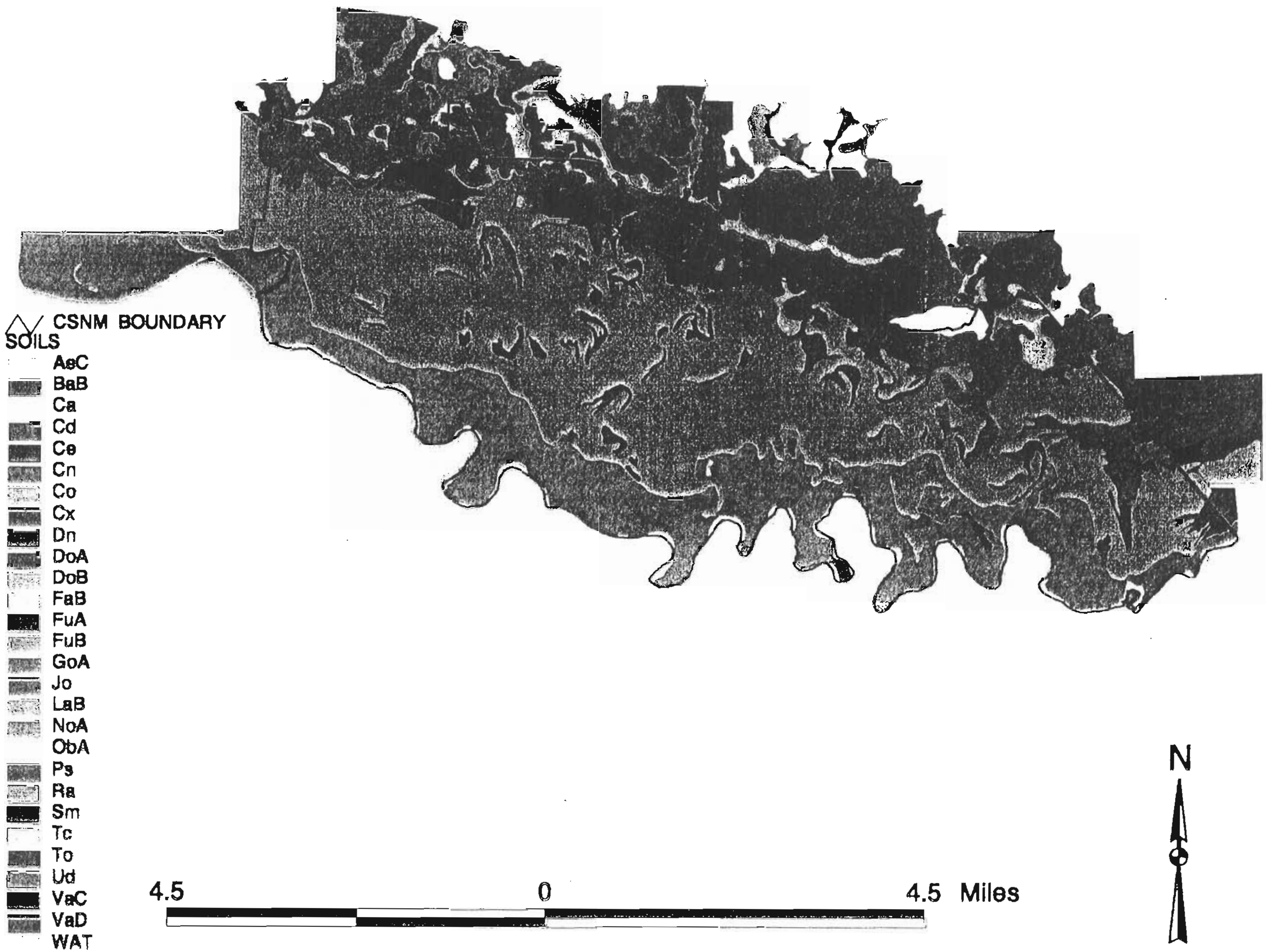


Figure 12.

HYDRIC SOILS

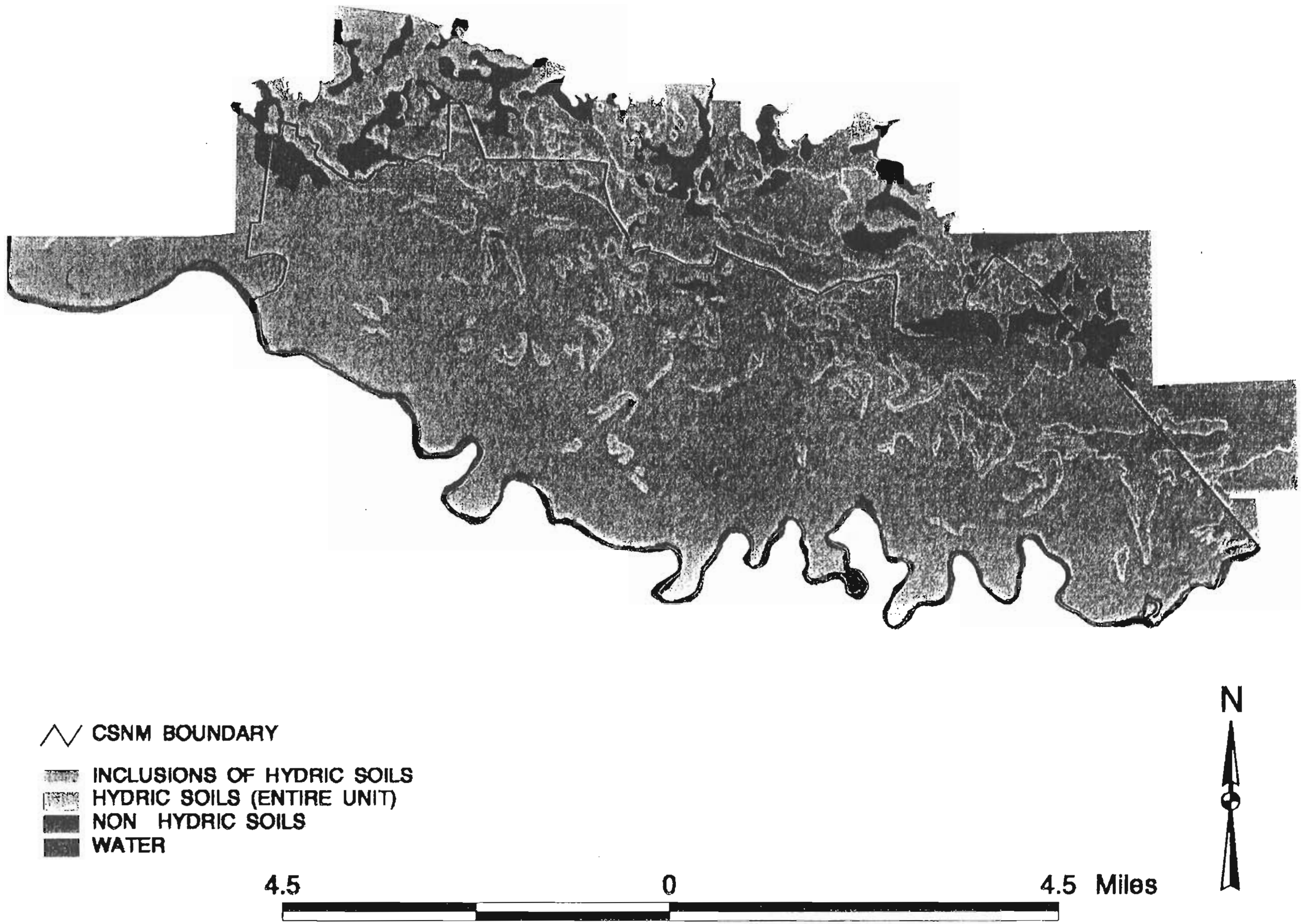
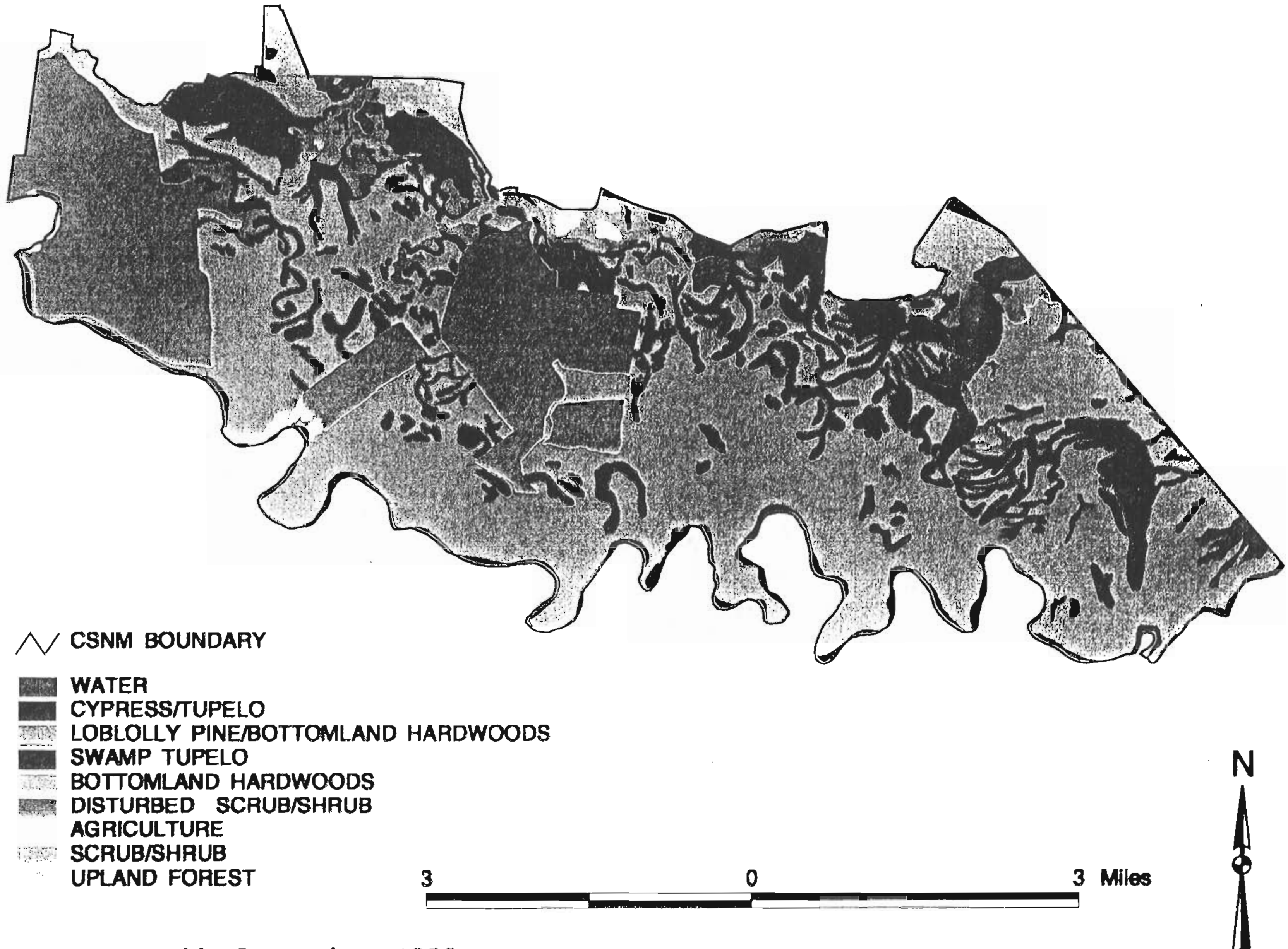


Figure 13.

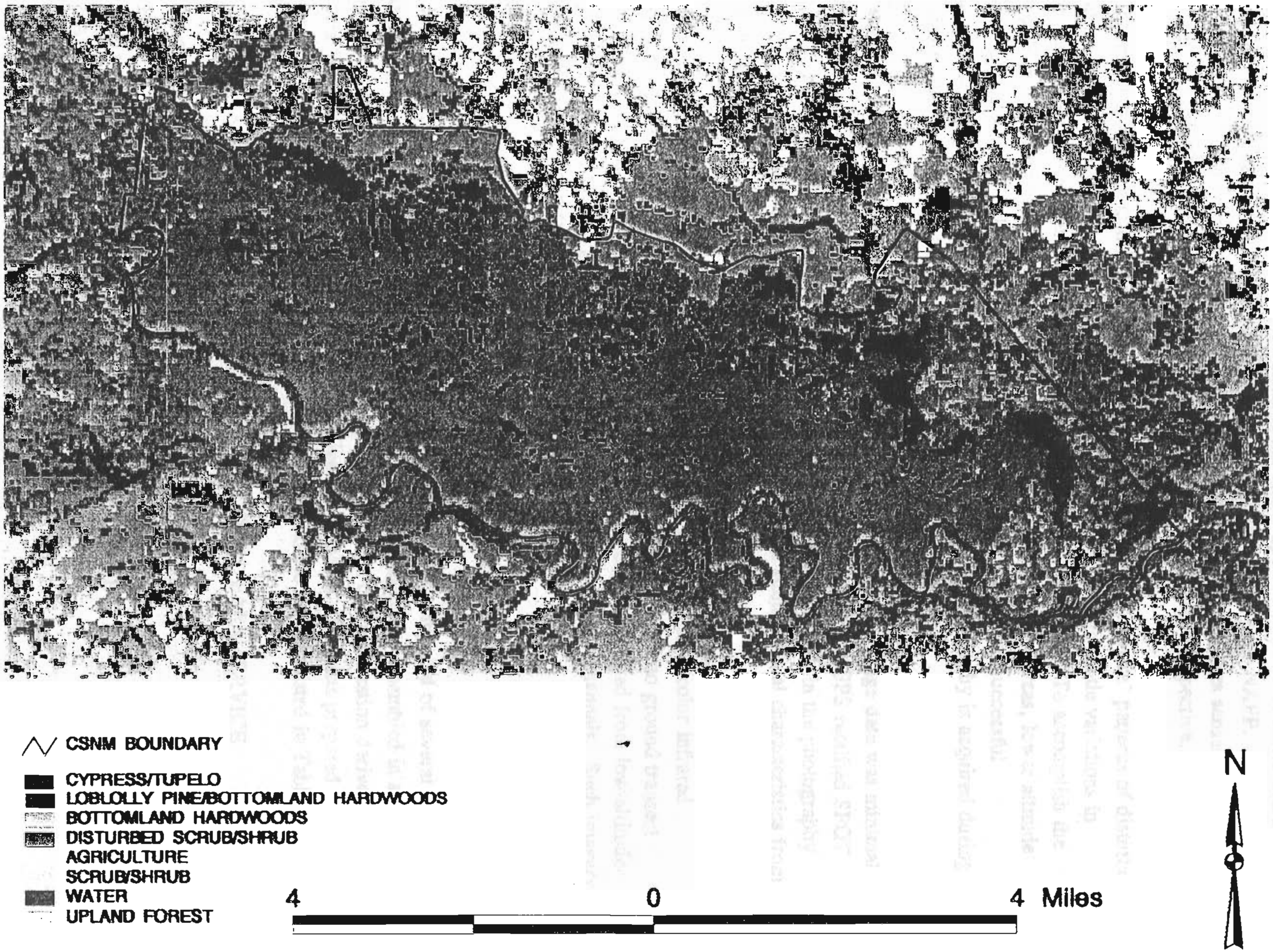
VEGETATION TYPES



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

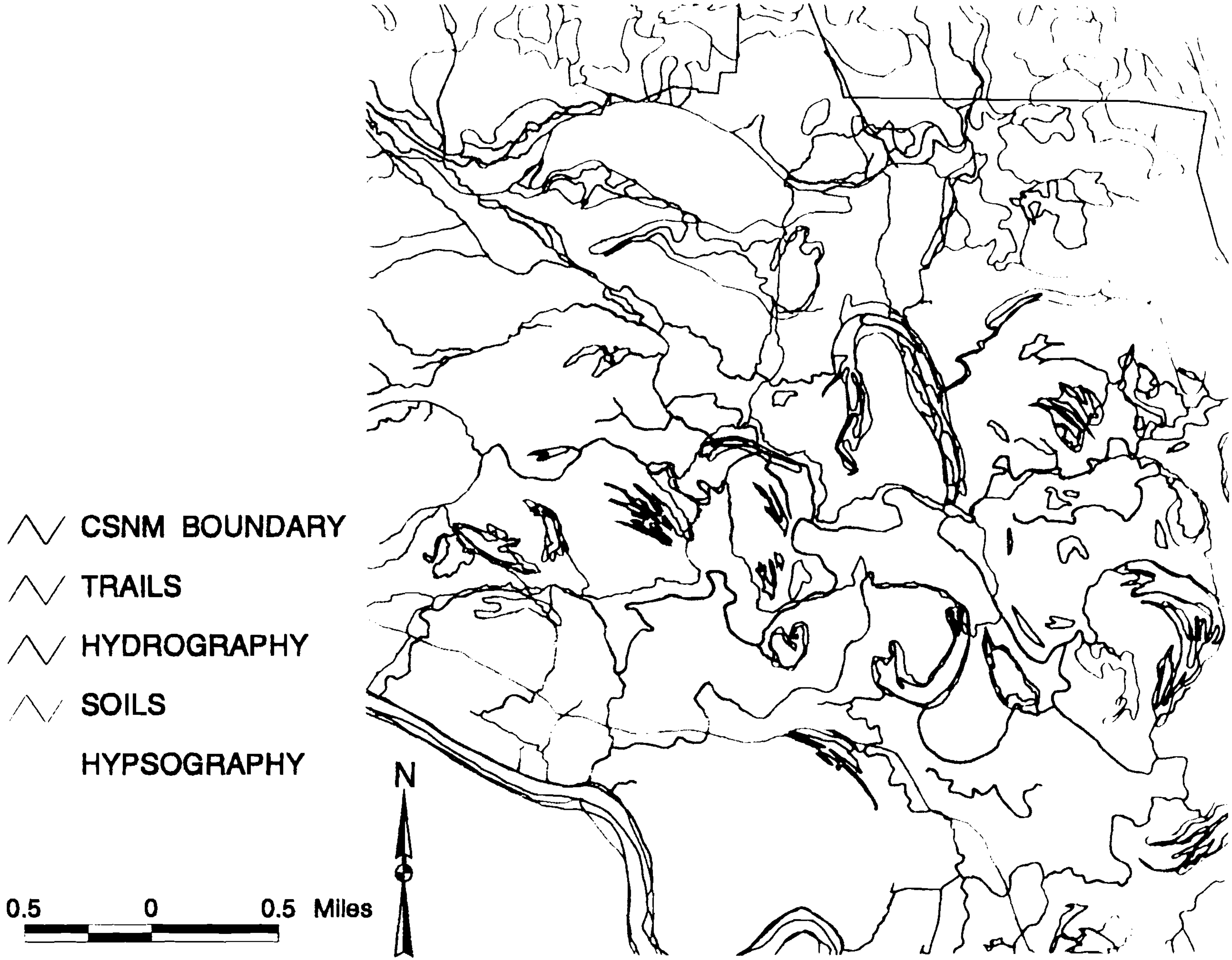


Table 2. LAYERS ASSEMBLED FOR MONUMENT GIS DATABASE

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

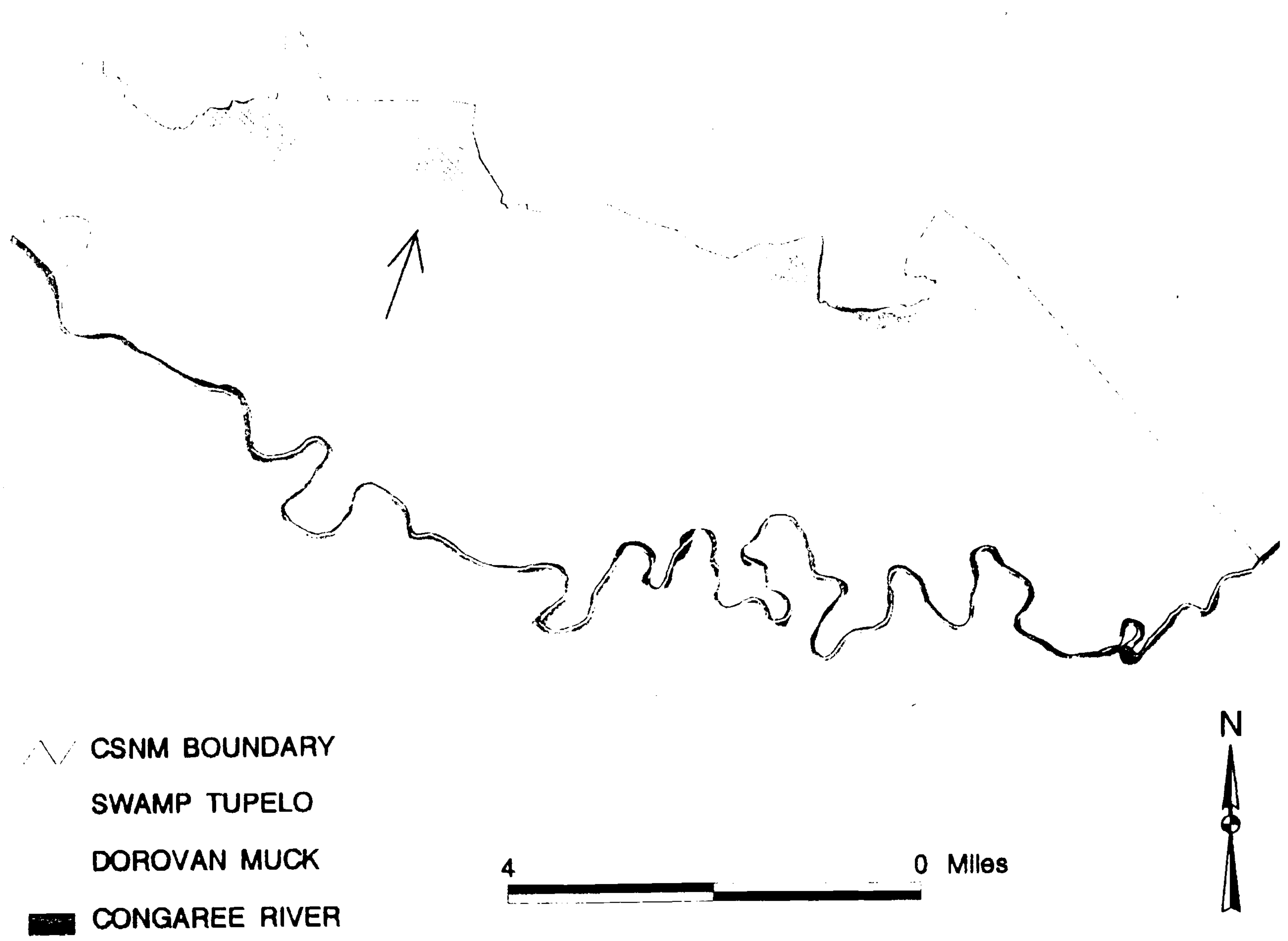
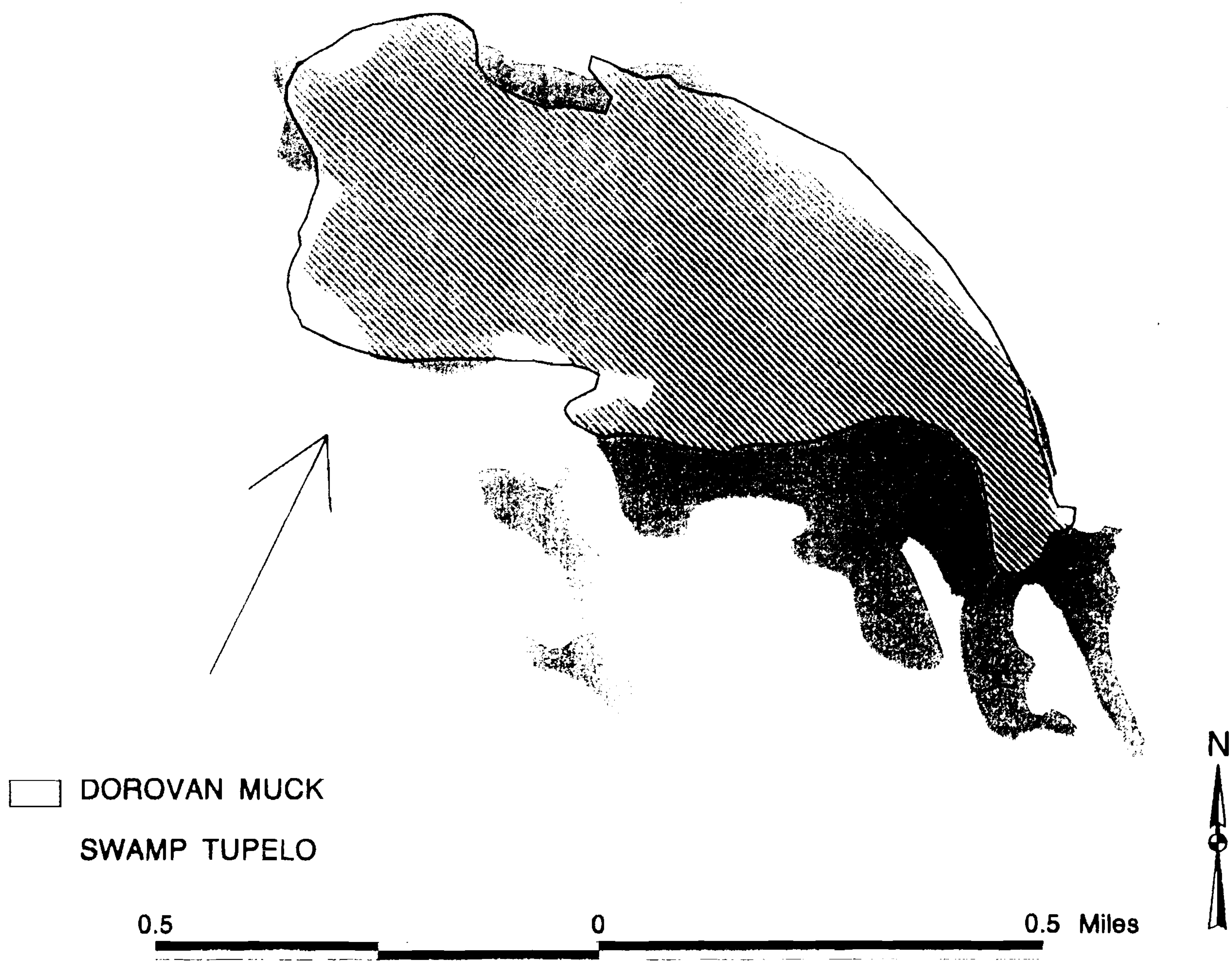


Figure 17.

DOROVAN MUCK / SWAMP TUPELO CORRELATION, SUBSET



Average distances between boundary lines of Swamp Tupelo and Dorovan Muck were 41.75 meters, ranging from 12 meters apart to 102 meters distance for the soils/vegetation data comparison.

Average distances between boundary lines of a Chastain silty clay loam from the soil survey and cypress/tupelo (PFO1/2) in an aggregated NWI dataset were approximately 31.0 meters due to planimetric dissimilarities between data sources and minor differences between the natural extent of PFO1/2 vegetation and Chastain soils. Average distances between boundary lines of aggregated NWI PFO1/2 and Smathers swamp tupelo stands were approximately 30.5 meters. Again, these differences result from both planimetric and scale differences in data sources and the different mapping approaches taken by NWI air photo interpreters with average 2% field verification frequency and Gaddy/Smathers techniques of on-ground observation with reference to aerial photography.

An insignificant difference was evident between raw image interpretation of the false color infrared composites for the pre-Hugo SPOT data and the post-Hugo TM data. This was due to their respective 20- and 30-meter spatial resolutions and to the phenomenon of confusion between storm damage (disturbance of the forest surface) and hydrologic complexity of the Swamp system which, by nature, appears "busy" from a vertical view. Hurricane disturbance was more readily evident in the post-Hugo NAPP photography, although only in a vague qualitative way and nearly impossible to quantify digitally based on photo interpretation. Manual on-screen digitizing from air photo interpretation proved unreliable since "blow-down" areas were consistently confused with guts and sloughs.

To overcome these barriers to clear definition of surface disturbances from storms like Hurricane Hugo, much lower altitude aerial photography is needed at a scale of 1:12,000 as compared to the 1:40,000 scale of the NAPP data. This would enhance the spatial resolution of the imagery from 1-meter to 1-foot resolution of each individual pixel. Vegetative patterns on the ground could be more easily resolved by the interpreter. The aerial photographic acquisition mission would have to be position controlled by real-time aircraft-borne GPS equipment providing accurate compensation for aircraft tip, tilt and trim. The photography could be subsequently rectified and serve as a base for the GIS data layers with sufficient detail to differentiate between blow-down shadows and complex swamp forest.

Discussion

Fundamental to any digital mapping based investigation involving layers of remotely sensed data is the coordinate base. This database assembly for the Congaree Swamp National Monument has required a number of highly detailed datasets. The first step is the establishment of a highly precise coordinate base to which all other data layers are georeferenced. GPS technology aided the creation of a sufficiently accurate ground control point (GCP) network for registration of other data layers to a geometrically corrected base. The accuracy obtained is within 5 meters of true geographic location.

One inherent challenge in mapping the Congaree Swamp is difficulty in identifying GCPs in the establishment of a coordinate base. Normally, road intersections in non-wetland areas are used as GCPs and are readily identifiable in color infrared aerial photographic and satellite image datasets.

These GCPs do not exist in the undeveloped swamp. The result was a set of 115 points on the ground found in areas adjacent to the floodplain, rather than within it. The Monument database is built upon coordinates that are highly precise in perimeter portions of the study site, with less precision across the central Swamp. The resulting database is, however, the most planimetrically accurate, to date. All prior inventory and mapping of the Monument has been based on USGS 7.5-minute quadrangles whose construction is also dependent upon scarce GCPs.

According to Dr. Robert H. Jones, Forest Researcher and Assistant Professor for Virginia Polytechnic Institute and State University (Virginia Tech), who is extremely familiar with the Monument and currently working on the Big Tree Survey there, the geocorrected base in this effort represents a significant accomplishment in producing relatively high accuracies in dataset correspondence with respect to the compex nature of the Swamp and lack of easily recognizable landmarks.

It was also extremely challenging to identify common GCPs in other source maps for digital co-registration to the GPS rectified image base. Such datasets include the USGS blueprint paper map of surface hydrologic and topographic features; USDA/NRCS soil survey map sheets for Richland County, South Carolina, based on medium-to-large-scale, low-altitude, black-and-white aerial photography with multiple photo centers per photograph and multiple radial distortion points per soil sheet; and USFWS/NWI maps based on USGS 7.5-minute quadrangles (Gadsden and Wateree). In these instances of unidentifiable common GCPs, the mapped information was best-fit to the GPS-corrected SPOT base image by matching identifiable common features such as levees on the Congaree River and "hard" points such as the corners of oxbow lakes for systematic co-registering.

Dr. Rebecca R. Sharitz, Senior Research Ecologist for the Savannah River Ecology Laboratory, University of Georgia, characterizes this effort as successful in co-registration of data layers from disparate sources and mutually overlaying them, key to simple comparisons between resource datasets to show relationships among Swamp wetland attributes qualitatively.

Another significant finding of the investigation has been the importance of obtaining the highest possible quality, scanned air photo data relative to image darkness and non-uniform contrast across different frames of a mosaic. This is a challenge for digital photo-reprographic industry because scanning of aerial data requires high quality input products (color positive transparencies, copy negatives or color internegatives). The non-uniformity of the scanned NAPP data was primarily attributed to dissimilarity of ranges in brightness values across the 16 input transparencies. This was mainly due to various flood conditions of different acquisition dates of individual photo frames.

A second pair of pre- and post- Hurricane Hugo scanned NAPP datasets was acquired through HAS Images, Inc. labs in Dayton, Ohio at a higher spatial resolution of 1.2 x 1.2 meters. In addition, pre- and post- Hurricane Hugo hardcopy mosaics were reproduced. Despite 2 x 2 meter resolution of the SREL scanned NAPP data and 1.2 by 1.2 meter resolution of the HAS data, it was unexpectedly difficult to identify vegetative communities by traditional air photo interpretation techniques.

Dr. Bob Jones of Virginia Tech found that the NAPP photos were difficult to use in general and nearly impossible to see large tree crowns, therefore of limited utility for his big tree survey, according to professional opinion stated in personal correspondence. Mr. Frank Draughn, Regional GIS Coordinator for the National Park Service, agreed in personal communication that it would be difficult to use digitally scanned NAPP data for determining subtle differences between Hugo-related blow-down and normal complexity of the Swamp surface; although traditional methods of zoom-transfer scope air photo interpretation combined with distirtion removal would yield successful results in pre-/post-Hugo change detection and damage assessment in the Monument.

Mr. Joel Wagner and Ms. Leslie Armstrong, resource and GIS managers with the National Park Service, believe that current color infrared (CIR) air photo scanning technologies should yield sufficient quality digital data for adequate interpretation of damage related change detection for the Monument. Indeed, the Department's Southeastern Remote Sensing Center (SERSC) personnel have had recent success with a local photo scanning company in Columbia, South Carolina (Visual Graphics, Inc.) in terms of NAPP image quality; while planimetric accuracy and precision of these data for a coastal area of the state are currently being tested. Furthermore, the SERSC has recently developed techniques for more uniform, continuous classification of these CIR (multispectral) air photos using the most recent version of Earth Resources Data Analysis Systems (ERDAS) raster image processing software, the 8.2 "Imagine" ERDAS software. Surprisingly smooth land cover data has recently been mapped in a South Carolina coastal area.

Overlay analyses indicated subtle differences between the classification schemes of the detailed Smathers vegetation data, aggregated vegetation data, NWI data, re-aggregated general land cover data from SPOT, and NAPP interpreted data. Certain combinations of datasets yielded specific characterizations of the Swamp including wetness characteristics. These data comparisons yielded some interesting results in the identification of wetland communities. The main wetland vegetative communities partially identified by satellite image derived land cover classifications were bottomland hardwood, mixed bottomland hardwood/pine, bald cypress/water tupelo, swamp tupelo, and fformerly clearcut/scrub-shrub.

These general vegetative communities are similar to those thought to be identifiable by the original project advisory team which met in the spring of 1994, including L.L. (Chic) Gaddy (consultant), Rebecca Sharitz (SREL), Eric Pauley (SREL - a new project consultant), and Rick Clark (resource manager). In independent project reviews, Robert Jones (Virginia Tech) and Robert Somers (Chief, Agricultural Protection Unit, New York State Department of Agriculture and Markets, a forester and soil scientist) agreed that these general vegetative communities could be identified realistically in the complex Swamp environment rather than individual tree species.

Dr. Jones believes "that only major vegetation types could be interpreted from the remotely sensed data. One reason for this is the incredible complexity of the forest communities in the swamp. In my mind, this complexity defies the idea of community classification, even if very detailed ground samples were taken. The classes: pine-bottomland hardwood, bottomland hardwood, cypress-tupelo, swamp tupelo, and recently harvested make sense to me. I wonder if a more detailed classification is necessary. Structure (e.g., size class distribution of trees) of the forest may impact wildlife habitat and recreational value more than does a minor shift in tree species composition."

These useful comments address the insightful analysis of Mr. Wagner and Ms. Armstrong when they consider the exact needs of the Park Service contained in their 1995 project review. "The park needs to answer whether the proper vehicle for change detection is change in vegetation cover or change in wetland boundaries and classifications. That is, is the park concerned more that wetlands are changing to other Cowardin classes (i.e., different water regimes or different vegetation structures or compositions) or to upland, or is it sufficient to simply document vegetation cover changes regardless of wetland or upland classification? (The wetland inventory would be harder to do than vegetation cover and would reqiure much more groundtruth data, but ultimately the wetland maps would provide more information)."

Clearly, this is the central debate for the Monument and the monitoring and management of its wetland resources through time. Ideally, the short-term solution for the Service is to use the wetland resource characterization database produced by this effort to develop a general vegetative community dataset for the entire Monument, rigorously prepared and groundtruthed by those conversant in both species/community identification and remote sensing/GIS, a simpler aggregate version of the Gaddy/Smathers vegetation work (1979/1980). The long-term solution for the Service is to develop or have developed a new, post-Hurricane Hugo National Wetlands Inventory according to the Cowardin classification system, including all possible modifiers. These additional eforts will provide a sufficient baseline for continuing scientific research and informed resource management.

The development of the public education module has been a challenging aspect of the project, both in terms of designing conceptual approaches to learning about the Monument's wetland systems and accomplishing the execution of interactive procedures for effective use by both visitors and park managers. Educators and students in the South Carolina school system who have come in contact with the module in its developmental stages have been favorably impressed by the capability of interacting with the module. Modules have been prepared based on both the EPPL-7 and ARCINFO software packages to be incorporated into the Monument's computing system upon installation. Within EPPL-7 (produced by the Minnesota Land Management Department), users can perform sub-routines describing the Monument's location and function statewide, its remotely sensed data layers, its GIS data layers, and zoomed-in exercises for the Weston Lake sub-area. Within ARCINFO (produced by Environmental Systems Research Institute), a complete database query and zoom-in system is provided.

A tutorial for the public education module appears in Appendix 1, "GIS Database Menu System." This module serves as an Operations Manual for the use and interpretation of data layers in the GIS depicting the Monument's wetland resources. This module has been prepared for the UNIX oerating system environment found aboard SUN SPARCstation hardware platforms and other similar UNIX workstation platforms.

Future Work

It is recommended that the National Park Service acquire a complete computer mapping capability to use this database to the fullest extent possible. This project represents a considerable effort in terms of an enormous quantity of labor spent in the design, construction, coregistration, fine-tuning and final preparation of the wetland resource database for the Monument and its environs. Future scientific investigations and research can draw upon this substantial GIS foundation to increase the knowledge-base of the unique and valuable assets found in this extraordinary environment.

The Southeastern Remote Sensing Center (SCDNR) will continue to support efforts by the Park Service through its Monument staff and associated scientific researchers to effectively use and develop the data described herein, specifically, by offering training in the use of GPS equipment and GIS data layers, production of digital maps for inclusion in various investigations, and air photo interpretation of NAPP 1:24,000-scale prints for Hurricane Hugo damage and change using zoom-transfer scope equipment. This continuing support of project related work will be provided during the year following this project.

The South Carolina Department of Natural Resources is committed to continuing support of research activities at the National Monument, by or under management of the Park Service, and looks forward to future cooperative efforts and work projects with the National Park Service as they may develop. The Department has enjoyed an excellent working relationship with representatives of the Service and considers there to be numerous areas of common mutual interest between the agencies. The Department concludes this particular joint effort with a sense of significant contribution to an understanding of the nature of the Congaree Swamp environmental system and welcomes further opportunities for joint efforts with the Park Service. This final report is respectfully submitted through Rick Clark, Government Technical Representative, to the Southeast Regional office of the National Park Service.

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Appendices

Appendix A. GIS Database Menu System

Based on Research by Thomas P. Curley (1994),
S.C. Department of Natural Resources

INTRODUCTION

The South Carolina Department of Natural Resources Land Resources and Conservation Districts Division (SCDNR-LRCDD) Southeastern Remote Sensing Center has created several layers of digital geographic information concerning the distribution of natural resources within the Congaree Swamp National Monument. These various layers of digital information, or themes, can be used for resource management, public education, and other specialized uses. The completed layers of digital information can be overlaid and compared for interaction and correlation analysis.

The SCDNR-LRCDD Southeastern Remote Sensing Center has created an easy to use menu driven analysis and display system designed specifically for the Congaree Swamp data layers. This menu system has the capability to display eight different layers of geographic information, perform simple analysis and query of these data layers, as well as map composition capabilities. The menu system also allows for selecting data layer features of interest and selectively displaying these areas of interest.

The menu system was designed for use in a UNIX operating system environment, and was written in WORKSTATION ARC/INFO programming ARC MACRO LANGUAGE.

The following manual explains some of the capabilities and uses of the menu system, and provides section-by-section descriptions of how to run the system.

MENU SYSTEM CHARACTERISTICS

The Congaree Swamp Geographic Information menu system consists of a series of small menus designed to run in the ARC/INFO display module ARCPLOT. The menus are all manipulated by pointing and clicking using the mouse cursor on the screen. Menu selections are made by pointing to the appropriate menu item selection and clicking or dragging using one of the three mouse buttons. The menu items call up AML routines which perform the function requested by the user. There is some interaction between the menu system and the operating command window in the UNIX environment which requires some user input, and is explained within this manual.

The menu system consists of a main menu which calls upon some smaller sub-menus which perform analysis and map composition functions. There are approximately 30 different AML programs that make up the menu system, and each routine can be modified and adapted to perform different functions. The total hard disk space occupied by these programs is approximately 10,000 bytes (10k), but the corresponding database of information layers takes up a great deal more space, about 40 megabytes total.

In the UNIX operating system, there will be two windows of concern when the menu system is invoked: (1) the display window and (2) the command tool window. The display window is the large black area in which the data layers and images will be displayed. The command tool window is the link to ARC/INFO and it is the location where data query values, measurement values, and parameter question prompts will be displayed. It is necessary in some operations to move the mouse cursor into the command tool window and type in text at appropriate prompts in order for the menu system to process commands.

MENU OPERATIONS

(Note: all text that needs to be typed is surrounded by the characters < and >; it is not necessary to type these characters in order to invoke commands.)

To invoke the menu system in ARC/INFO, enter the ARCPLOT module at the ARC prompt. At the ARCPLOT prompt it is necessary to set up the display window by typing < DISPLAY 9999 3 >. Now run the main AML program which sets up the entire menu system by typing < &R MENU >. This command will show the main menu in the upper left corner of the display window, the top of the main menu is labeled 'CONGAREE SWAMP N. M.'.

There are 7 main menu choices listed on the menu. Each choice is seen as a raised button area. The buttons with a small arrow on the right side of the button have associated sub-menus containing more menu choices.

MAIN MENU CHOICES

Display Image: This menu choice displays one of the three satellite images covering the Congaree Swamp study area.

Display Data Layer: This menu choice displays one of the eight data layers created for the Congaree Swamp project.

Zoom: This menu choice allows the user to define the viewing area of the Congaree Swamp data layers.

Query: This menu choice enables data querying of the displayed data layers.

Analysis: This menu choice brings up a sub-menu from which various simple measurements and analyses can be performed.

Map Composition: This menu choice calls up the MAPEDIT menu which can be used to create map compositions for data display and output.

Clear: This menu choice clears the display window.

Quit: This menu choice allows the user to leave the menu system and puts the user back at the ARCPLOT prompt.

MENU CHOICE DESCRIPTIONS

Display Image: This menu choice has a sub-menu associated with it which is viewed by pressing and holding the right mouse button while moving the mouse cursor to the right. The choices in the sub-menu include the three satellite images covering the swamp. They are chosen by moving the mouse cursor down over the sub-menu until the desired sub-menu choice is highlighted and then releasing the right mouse button. The selected image will then appear in the display window.

Display Image Sub-Menu Choices
SPOT Image: Displays the rectified raw (original color infrared false color composite) 1989 SPOT image of the swamp.

Supervised Classification: Displays the classified raw SPOT image created using a supervised classification algorithm. The legend can be viewed in the command tool window by choosing the SHOW LEGEND sub-menu choice.

Unsupervised Classification: Displays the classified raw SPOT image created using an unsupervised classification algorithm. The legend can be viewed by choosing the SHOW LEGEND sub-menu choice.

Show Legend: Displays the color names and corresponding class types in the command tool window.

Display Data Layer: This menu choice has a sub-menu associated with it which is viewed by pressing and holding the right mouse button while moving the mouse cursor to the right. The choices in the sub-menu include the eight digital data layers within the swamp. They are chosen by moving the mouse cursor down over the sub-menu until the desired sub-menu choice is highlighted and then releasing the right mouse button. The chosen data layer will appear in the display window.

(NOTE: If an image is already shown on the display window, any chosen data layers will be drawn on top of the image; but displaying an image on top of already showing data layers will cover up the displayed data layers.)

Display Data Layer sub-menu choices

Monument Boundary: Displays the Congaree Swamp National Monument Boundary in red.

Hydrology: Displays the Swamp hydrology in light blue, including streams, lakes, and saturated swamp areas.

Wetlands: Displays the National Wetlands Inventory polygons in purple.

Elevation Contours: Displays the 4-foot interval elevation contours in orange.

Trails: Displays the public trails maintained by the National Park Service in yellow.

Soils: Displays the soil type polygons in gray.

Vegetation Types: Displays the vegetation type polygons in green digitized from the 1980 Gaddy-Smathers vegetation map.

Study Plots: Displays the National Park Service study plots located throughout the swamp in white.

Zoom: This menu opens a sub-menu which has two choices. These choices are selected by the same point and click mouse cursor routine. This menu choice adjusts the viewing area of the display window. The zoom option does not redraw any previously displayed data layers or images, they must be redrawn after a ZOOM function is chosen by selecting the DISPLAY IMAGE or DISPLAY DATA LAYER options.

Zoom sub-menu choices

Zoom In: When this option is chosen, a cross-hair will appear in the center of the display screen. Define the zoom in area by moving the cursor to a location and clicking the left mouse button and then move the mouse to adjust the box size. Click the left mouse button again when the desired zoom area is defined. The display window will clear, data layers must be redrawn and will appear magnified to the defined zoom area specifications.

Zoom Out: This option resets the magnification to 0 and clears the display window. Data layers must be redrawn using the appropriate menu choices.

Query: This menu choice opens a sub-menu which lists the different query choices. These choices allow the user to select and display the data about a feature in a **displayed** data layer and lists the data in the command tool window. When query options are chosen, a cross-hair will appear in the display window. Move the cross-hair to select a data layer polygon or line and click the left button. The data values for that particular polygon or line will appear in the command tool window.

Query sub-menu choices

Query Wetland Layer: This option allows the user to move the cross-hair to any wetland polygon area displayed in the display window and click to read the data attribute information assigned to the chosen polygon. The information assigned to the wetland polygon will be displayed in the command tool window. The wetlands coverage includes polygon area in square meters, polygon perimeter in meters, and the generalized wetland class (Appendix 2).

Query Trails Layer: This option displays attribute information assigned to each trail displayed in the display window. To query a trail, move the cross-hair to a trail and click on the trail with the left mouse button. This will display the trail information for the selected trail in the command tool window. The trail attributes include 'TRAIL' (Trail name) and 'TOTLENGTH' (total length in kilometers).

Query Soils Layer: This option displays attribute information assigned to the soil layer. To query a soil polygon, move the cross-hair into the desired polygon and click the left mouse button. The information assigned to this soil polygon will be displayed in the command tool window. Information assigned to the soils layer include the polygon area in square meters, soil series, and soil type (Appendix 3).

Query Vegetation Layer: This option displays attribute information assigned to the vegetation layer. To query a vegetation polygon, move the cross-hair into the desired polygon and click the left mouse button. The information assigned to this vegetation polygon will be displayed in the command tool window. Information assigned to the vegetation layer include the polygon area in square meters, 'VEGCODE' (Gaddy Smathers class value), and 'ICLASS' (Generalized vegetation type class - see Appendix 4).

Analysis

This option allows for some topical analysis of the Congaree Swamp database. Any serious analysis should be done outside of the menu system in the ARC environment. When this option is chosen a sub-menu will appear which allows for selective data analysis, length measurements, area measurements, and positional information. The selective analysis sub-menu options open different menus from which polygon types may be selected and displayed.

To select an option from the sub-menus, hold the right mouse button down on the main menu choice and move the cursor to the sub-menu and move down until the desired option is highlighted, then release the mouse button to invoke the operation.

Analysis sub-menu choices

Select Polygon Features: This option selects polygon features according to their data values. This sub-menu option calls up another menu which contains three polygon coverage choices: wetlands, soils, and vegetation.

Polygon Analysis Menu

Select wetland polygons: This choice allows the user to select from the wetlands coverage any of the 13 generalized wetland classes in the Monument. Once a selection is made, the selected wetland class type will be outlined and shaded in the display window.

Select vegetation polygons: This choice allows the user to select from the vegetation type coverage any of the 9 generalized vegetation classes in the swamp. Once a selection is made, the selected vegetation type will be outlined and shaded in the display window.

Measure Distance: This menu option when selected displays a cross-hair in the display window. Move the cross-hair to define a line length and press the left mouse button to insert vertices in the line. To end the line length press 9 on the keyboard and the distance of the line defined in meters will be displayed in the command tool window.

Get Coordinates: This menu option when selected displays a cross-hair in the display window. Move the cross-hair to the desired location and press the left mouse button. The UTM coordinates of the selected position will be displayed in the command tool window as 'MAP UNITS'.

Measure Area: This menu option when selected displays a cross-hair in the display window. Move the cross-hair to define a polygon area by pressing the left mouse button to add corners to the polygon. When the desired area is defined, press 9 on the keyboard and the area within the defined area will be displayed in square meters in the command tool window.

Clear: This menu option clears everything within the display window. It is not possible with this menu system to erase on displayed layer at a time. It is necessary after using this option to redisplay the desired data layers using the ***Display Data Layer*** menu option.

Quit: When selected, this menu option ends the menu program and puts the user in the ARCPLOT environment. To recall the menu system, type <&r menu>.

Creating Map Compositions With The Congaree Swamp Menu System

This menu system takes advantage of the ARCPLOT ability to create and display map compositions. Map compositions are created for display and output purposes, combining data layers and appropriate text, legends, and other annotation. Map compositions create a 'picture' of the display window with all the data displayed and associated text, which can be displayed easily using the ARCPLOT command PLOT (PLOT <filename>).

To begin a map composition, the name of the composition must be defined. Once the map composition is named, the pagesize of the composition must be defined. The map composition itself is created by displaying the desired data layers and adding text, titles, legends, and other annotation. While in a map composition, any of the elements in the composition can be selected and manipulated to correct errors in placement or spelling. Once the map composition is completed, the composition must be ended to save all of the displayed map elements. The Congaree Swamp Menu system incorporates all of these steps into an easy to use series of menu selections.

Using the menu system, a new map composition can be created using the ***Begin*** sub-menu option of the ***Map Composition*** menu option or an existing composition can be edited using the ***Edit Existing Map*** sub-menu option of the ***Map Composition*** menu option. Once the map composition has been created, data layers can be displayed by selecting the ***Return To Main Menu*** option of the map composition menu and then selecting the appropriate menu display options from the Main menu.

Manipulating elements within the map composition requires a two step process: first select the element using the ***Select Element*** option of the Map Composition menu and then manipulate the selected element using the ***Manipulate Element*** option of the Map Composition Menu. If text is to be added to the map composition, select the ***Text*** option of he Map Composition Menu. When the composition is completed, select the ***Save and End*** sub-menu option of the ***Map Composition*** option in the Map Composition Menu.

The following is a description of how to operate the Map Composition Menu options.

Select Element: This menu option allows the user to select map elements to be manipulated.

Select Element sub-menu

Select Many: When this option is selected, cross-hairs appear in the display window. Move the cross-hairs to the element(s) to be selected and press the left mouse button to select them. When finished selecting elements, press 9 on the keyboard and manipulate them with the

Manipulate Elements option.

Select All: When this option is selected, all of the map elements are selected. All of these selected elements can then be manipulated using the **Manipulate Elements** option.

Unselect: When this option is selected, cross-hairs appear in the display window. Move the cross-hairs to the selected element(s) to be unselected and press the left mouse button to unselect them.

Unselect All: This option unselects all of the selected elements. **Manipulate Element**: This menu option allows the user to manipulate items that have been selected using the **Select Element** menu option.

Manipulate Element sub-menu

Move: When this option is chosen, cross-hairs appear in the display window. Move the cross-hairs to the position to move a selected element from and press the left mouse button, then move the cross-hairs to the position to move the selected element to and press the left mouse button. When finished, type 9 and the selected items will move to the new position.

Rotate: This option rotates selected elements a defined degree value between 0 and 360. Enter the desired rotation amount in degrees in the command tool window where prompted and press ENTER to rotate.

Delete: This option deletes all selected elements from the map composition.

Map Composition: This menu option creates, edits, saves, and ends map compositions. These functions are performed when selected from the sub-menu choices.

Map Composition sub-menu

Begin: This option creates a new map composition and prompts for a composition name and pagesize parameters. Enter the composition name, page length, and page height in the command tool window at the appropriate prompts. When this is completed, the composition is ready to be created.

Edit Existing Map: This option allows for editing of previously existing map compositions. Enter the name of the composition to be edited in the command tool window and it will be plotted in the display window, ready for any changes. After changes are made, save the map composition using the ***Save and End*** menu operation.

Save and End: This menu option saves and then ends the map composition session. In order to reopen the map composition, use the ***Edit Existing*** menu option.

Text: This option allows the user to enter text strings and place them into the map composition. When invoked, an 'ENTER TEXT STRING' prompt will appear in the command tool window. Type the desired text string in single quotes and press ENTER.

NOTE: the text string must always be in single quotes (eg. 'CONGAREE SWAMP DATABASE'). After the text string is entered, a prompt for textsize will appear in the command tool window. Type in the textsize desired in inches and press ENTER (ex. .3). After ENTER is pressed, cross-hairs will appear in the display window. Move the cross-hairs to the desired location for the text string and press the left mouse button, the text will be displayed at this location.

Accessing and Editing the Congaree Swamp National Monument GIS Database Values

The data layers created for the Congaree Swamp National Monument can be changed and augmented. To gain access to the data layers go to the ARC prompt and type <TABLES>. Tables is the database manager for ARC/INFO and this is where all of the data editing occurs. Once in tables type <select <filename>.aat> to access the data for <filename>. To change values use the UPDATE command, to view the values use the LIST command, and to quit TABLES type <Q STOP>. Type <HELP> for a list of Tables commands and <HELP<command> > to get help for a specific command.

Appendix B. Generalized Wetland Classes

Based on September 1988 Position Paper
by John M. Hefner, Regional Wetlands Coordinator
National Wetlands Inventory
U.S. Fish and Wildlife Service
Atlanta, Georgia

GENCLASS	GENERAL WETLAND CLASS	DESCRIPTION
PBP	Ponds and Borrow Pits	Small fresh water bodies less than 2 acres in size
UF	Unvegetated Flats	Areas with less than 30% vegetative cover which are periodically flooded by fresh water.
SWM	Savannahs & Wet Meadows	Herbaceous areas which are flooded only briefly but which may be saturated for long periods during the growing season. Species include pitcher plants, sundews, pogonias, pipeworts, meadow beauties, orchids, yellow-eyed grasses, asters, and goldenrod.
FM	Freshwater Marshes	Herbaceous areas which are flooded during the growing season. Included within this type are fresh tidal marshes, marshes within managed impoundments, and naturally occurring on-tidal marshes. A tremendous variety can occur. Representative species include sedges, millets, rushes, maidencane, arrow arum, smart weeds, pickerelweed, arrowheads, and cattails.
PSW	Pine Savannahs & Wet Flatwoods	Areas dominated by slash pine, pond pine and occasionally loblolly pine. The water table is occasional and flooding or ponding occurs briefly during the growing season.

GENCLASS	GENERAL WETLAND CLASS	DESCRIPTION
BH	Bottomland Hardwoods	Forested areas usually occurring within floodplains. Flooding usually occurs in the winter and spring. Species include hickories, overcup oak, water oak, laurel oak, beech, sweetgum, green ash, cottonwoods, willows, river birch, and loblolly pine.
WS	Wooded Swamps	Often associated with floodplains, occurring on low flats, sloughs and oxbows, and in isolated ponds. Flooding may take place for several months during the growing season to nearly year round. Tree species include green ash, water hickory, red maple, overcup oak, cypress, and tupelo.
BF	Bay Forests	Often called "bayheads", located on poorly drained flats, in shallow depressions in Carolina bays, and in coastal ridge and bay (swale) topography. mainly occurring on peat soils, these areas stay saturated for long periods during the growing season. Dominant species include red bay, sweet bay, loblolly bay, swamp tupelo, red maple, cypress, and pond pine.
ESB	Evergreen Shrub Bogs	Called "pocosins", maybe the fire dominated early successional stage of the evergreen forest community. Locations and water regimes are similar. Dominant species are sweet gallberry, fetterbush, titi, sweet bay, red bay, and zenobia.

GENCLASS	GENERAL WETLAND CLASS	DESCRIPTION
DSS	Deciduous Shrub Swamps	Usually an early successional stage of the wooded swamp community. These habitats are often the result of clearcutting, beaverponds, or disturbance. Plant species may include button bush, alder, red maple, sweetgum, or willow.
RC	Rivers and Canals	Channels which at least periodically carry water with salinities less than 0.5 parts per thousand.

List of MONUMENT-WIDE aggregated classes and NATION-WIDE individual classes:

Ponds and Borrow Pits:	PUB
Unvegetated Flats:	PUS
Savannahs/Wet Meadows:	PEM1A, PEM1B, PEM1C, PEMA, PEMC
Freshwater Marshes:	PEM1F, PEM1H, PEM1K, PEM1Mh, PEM1N, PEM1P, PEM1R, PEM1T, PEMFx, PEM/SS1T, U/PEM1T
Pine Savannahs/Flatwoods:	PFO4A, PFO4C, PFO4R, PFO4S, PFO4/1A, PFO4/SS3A, PFO4/SS3C, PFO7A, PFO7S, PSS4A, PSS4C, PFOSS4A, PSS3A
Bottomland Hardwoods:	PFO1A, PFO1S, PFO1/2A, PFO1/3A, PFO1/4A, PFO1/4S, PFO1/SS3A, PFO1/SS4A, PFO1/4C, PFO1/4R, PFO1/SS4R, PFO4/1C, PFO4/1R, PFO/SS1C, PSS1A, PSS1S, PSS1/3A, PSS1/3S, PSS1/4A, PSS1/4C, PSS3/1A, PSS6Ad, PSS6S
Wooded Swamps:	PFO1B, PFO1C, PFO1F, PFO1G, PFO1P, PFO1R, PFO1T, PFO1/2, PFO1/3C, PFO1/3R, PFO1/SS3C, PFO1/SS3F, PFO1/SS3R, PFO2, PFO5, PFO6C, PFO6F, PFO6G, PFO6N, PFO6/EM1C, PFO/EM1F, PFO/SS6Fh, PFO/SS6T, PFO/SSFh, PFO/SS6T
Bay Forests:	PFO1/3B, PFO1/4B, PFO1/SSB, PFO3/SS1B, PFO4B, PFO4/1B, PFO4/2C, PFO4/3C, PFO4/SS1B, PFO4/SS3B, PFO7B, PFO7C, PFO7Kh, PFO7R, PFO/SS3B
Evergreen Shrub Bogs:	PSS1B, PSS3A, PSS3B, PSS3C, PSS3R, PSS3S, PSS7A, PSS7b, PSS7C, PSS7F, PSS7R, PSS1/3B, PSS1/4B, PSS3/1A, PSS3/1B, PSS3/1C
Deciduous Shrub Swamps:	PSS1C, PSS1F, PSS1N, PSS1R, PSS1T, PSS2Kh, PSS6C, PSS6F, PSS6K, PSS6M, PSS6N, PSS6R, PSS1/2F, PSS1/2T, PSS1/3C, PSS1/3F, PSS1/3H, PSS1/3R, PSS1/3T, PSS1/4T, PSS1/7R, PSSC, PSS6/EM1F, PSS/EM1C
Rivers and Canals:	R1UB, R2UB, R2US

Appendix C. Soil Types of the Congaree Swamp

Based on U.S. Department of Agriculture,
Natural Resources Conservation Service,
Richland County Soil Survey

SERIES	DESCRIPTION
AeC	Ailey Loamy sand, 2 to 10 percent slopes
BaB	Blanton sand, 0 to 6 percent slopes
Ca	Cantey loam
Cd	Chastain silty clay loam
Ce	Chewacla loam
Cn	Clarendon sandy loam
Co	Congaree loam
Cx	Coxville fine sandy loam
Dn	Dorovan muck
DoA	Dothan loamy sand, 0 to 2 percent slopes
DoB	Dothan loamy sand, 2 to 6 percent slopes
FaB	Faceville sandy loam, 2 to 6 percent slopes
FuA	Fuquay sand, 0 to 2 percent slopes
FuB	Fuquay sand, 2 to 6 percent slopes
GoA	Goldsboro sandy loam, 0 to 2 percent slopes
Jo	Johnston loam

SERIES	DESCRIPTION
LaB	Lakeland sand, 2 to 6 percent slopes
NoA	Norfolk loamy sand, 0 to 2 percent slopes
ObA	Orangeburg loamy sand, 0 to 2 percent slopes
Ps	Persanti very fine sandy loam
Ra	Rains sandy loam
Sm	Smithboro loam
Tc	Tawcaw silty clay loam
To	Toccoa loam
Ud	Udorthents
VaC	Vaucluse loamy sand, 6 to 10 percent slopes
VaD	Vaucluse loamy sand, 10 to 15 percent slopes

Appendix D. Vegetation Types and Classes

Based on Gaddy/Smathers Vegetation Map (1980) and
Gaddy et al. (1975), (Gaddy 1979a), Gaddy (1979b)

ICLASS	VEGETATION CLASS (Gaddy-Smathers Map)
1 Cypress/Tupelo	26 Water Tupelo/Cypress
	5 Cypress *(Taxodium distichum)*
	25 Water Tupelo *(Nyssa aquatica)*
2 Loblolly Pine/ Bottomland Hardwood	12 Loblolly Pine/Bottomland Hardwoods
3 Swamp Tupelo	18 Swamp Tupelo *(Nyssa salvatica)*
	19 Swamp Tupelo/Others
	13 Loblolly Pine/Swamp Tupelo
4 Bottomland Hardwoods	4 Cottonwood *(Populus deltiodes)*
	27 Willow *(Populus heterohylla)*
	20 Sweetgum *(Liquidamber styraciflua)*
	21 Sweetgum/Mixed Hardwoods
	2 Bottomland Hardwoods
	9 Laurel Oak *(Quercus laurifolia)*
	10 Laurel Oak/Sweetgum
	15 Overcup Oak/Mixed Hardwoods
	17 Riverbank Hardwoods
	7 Green Ash *(Flaxinus sp.)*
	8 Green Ash/Red Maple
	6 Cypress/Bottomland Hardwoods
	14 Overcup Oak *(Quercus lyrata)*
5 Scrub/Shrub/Disturbed	28 Selectively Cut
	29 Clear Cut
6 Agricultural	1 Agricultural Crops
7 Scrub/Shrub	

ICLASS	VEGETATION CLASS (Gaddy-Smathers Map)
8 Water	
9 Upland Forest	3 Bluff Hardwoods 11 Loblolly Pine *(Pinus taeda)* 22 Upland Hardwoods 23 Upland Loblolly Pine 16 Pine Plantations 24 Upland Loblolly Pine/Mixed Hardwoods