What We've Learned About GIS

One Park's Experience in the World of Geographic Information Systems

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Preface

OVER THE PAST THREE YEARS Colonial National Historical Park has been developing a park-based PC-DOS Geographic Information System (GIS) under a cooperative agreement with the GIS Research Program of North Carolina State University (NCSU). During this development period we have received several dozen phone calls from other national parks, USNPS regions, other federal agencies, and state, local, and private organizations regarding our GIS experience. This article attempts to summarize both our positive and negative experiences in developing our GIS. We hope this will be of use to those planning to implement GIS.

Brief Description of GIS and Its Uses and Value

A Geographic Information System is basically a set of computer programs that allows the construction, display, and analysis of maps and their associated attributes (data)—e.g., type of well, length of stream, size of lake, type of forest vegetation, frequency a field is mowed, etc. All information in a GIS is georeferenced to a fixed point; that is, each point (e.g., well site), line (e.g., road or stream), or region (e.g., field, forest, lake) has a known geographic reference, often referred to longitude and latitude, or state plane, or universal transverse mercator (UTM). The use of maps and other drawings is a common activity shared by all the resource management, planning, and administrative functions of an organization. The use of GIS increases the comprehensiveness and efficiency of map use and the associated attributes.

GIS operates first by developing a computerized description of all the information contained on a map or drawing. Each point, line, and region on a map is translated into a series of code numbers (digits) and entered into the GIS computer software. This process is referred to as digitizing. Digitizing can be accomplished through:

- typing on a computer key-board;
- using electronic tracing tablets, called digitizers; or
- directly entering digital satellite remote sensing data.

The digitized media can be traditional maps or drawings, aerial photographs, satellite images, or digital descriptions of phenomena from surveyor's notes to electronic scanners.

The second step in GIS use is the manipulation of the digitized map information in the computer. This is the power of the system. A GIS can automatically change a map's scale, the number of features displayed, legends, and titles without having to redraw or photographically alter it. This is a major advance in both efficiency and completeness.

GIS allows for new information to be generated from the map base with remarkable savings of time and effort. Calculations of area (acreage of wetlands, open fields), linear distances (miles of fencing, roads, earthworks), adjoining property owners, slope and aspect, and many more analyses can automatically be determined with the GIS.

A major strength of GIS is the ability to combine maps and drawings of different scales and themes to develop maps that did not exist previously. For example, GIS can automatically combine a historic vegetation map with a map of present conditions to produce a new map highlighting areas of similarity and dramatic change. The final step in GIS application is the production of map documents (paper, mylar, video) for use in communication and management.

It is of particular importance in the use of GIS for parks that these output maps be of high quality both in accuracy and presentation. There is no loss in accuracy with most GIS programs. Presentation quality is usually better than manual methods, due to the efficiency of the automated plotting and the ability to quickly redraft drawings that need to be updated or changed. In essence a change in management perception is brought on by the use of GIS. With GIS, maps and drawings are considered transitional documents and are easily reproduced or redone. With traditional hand-produced maps and drawings, these products were the only data source and had to be thought of as archival material with little or no potential for redrafting or enhancement.

Applications of GIS can be quite extensive. The overriding importance of preservation of both cultural and natural resources, with the complexities that this entails, makes the potential for use of GIS in a park quite significant. For example, a GIS could be used to refine management plans for vegetation manipulation that would give full consideration to such diverse issues as historic vegetation conditions, viewsheds, wildlife concerns, wetlands disturbance, interpretive development, wildfire management units, maintenance scheduling, utilities and drainages, and law enforcement.

Developing GIS at Colonial National Historical Park

Colonial National Historical Park is a 9,324-acre park along the James and York Rivers, composed of Jamestown Island, Yorktown Battlefield, the Colonial Parkway, Green Springs, and Swann's Point. The development of GIS at Colonial has been phased in. Instead of a single centralized system the Colonial GIS provides distributive access to the database by historic interpretation and preservation, cultural resource management, natural resource management and visitor protection. The base system includes one 486- and three 386-based PCs, with GIS software and access to the database at three park locations.

The park has developed data themes for the GIS under cooperative agreements with NCSU's GIS Research Program, the College of William and Mary—Virginia Institute of Marine Science (VIMS), and the U.S. Department of Agriculture–Soil Conservation Service (SCS).

Also with NCSU assistance, we developed park GIS standard operating procedures to guide the development of new geographic and database files, database management, data dictionary, and cartographic map output.

GIS Planning

Any park considering the implementation of GIS needs to develop a GIS Management Plan. Colonial's plan was developed in the summer of 1990 and provides direction for program implementation (including a needs assessment), determination of priorities, and staffing, hardware, software, and data acquisition needs and cost.

The planning process began by educating Colonial employees about the likely uses of GIS. Several memos, including one on what GIS is and how it might be used at the park, were distributed. We also conducted a day-long introductory GIS workshop at the park attended by 20 park supervisors and division chiefs. The morning session covered principles of GIS, different types of automated mapping and GIS systems, GIS data structure, possible park GIS applications, system design alternatives, and short- and long-term costs. So that participants could relate to specific issues, some park themes were digitized and maps produced for the workshop. At each break, we observed that participants were looking at the maps with a new perception as they learned to recognize potential GIS applications in their operations. The USNPS Washington Office's 20-minute film on GIS was also shown. A hands-on approach was used during the afternoon session, wherein participants were led through an exercise using GIS software and a plotter. Intensive interviews were held over the next two days with different park work groups in all divisions to discern how the different divisions might use GIS and to set priorities for data themes (see Figure 1).

The GIS implementation decision for the park was based on three criteria: 1) the appropriateness of raster versus vector data structures, and the need to exchange digital data with other GIS users (local and state governments, university systems); 2) the ability to have several park divisions benefit from, and use, the GIS immediately; and 3) realistic staffing, budgeting, and training that could be committed to a GIS. The final plan allows for access to a PC-based GIS by the three major park divisions.

Cooperators

The use of university cooperators has been critical to the success of our GIS program. Graduate students become researchers and digitizers as they prepare their theses about different theme development projects. Also, it provides for better give and take than trying to go through private contractors to develop themes, receive training, and solve problems. Furthermore, there is little chance we could receive the equivalent of trained personnel and sufficient full-time employee positions (FTEs) from the park's base funding to develop a GIS. Thus, a university cooperator helps to greatly enhance park staffing and speeds the development of a GIS. Like any cooperative endeavor it requires lots of communication, give and take, and experimentation.

Figure 1. Themes Digitized at Colonial

NCSU GIS Research Program	forest cover, fields, wetlands (tidal and non-tidal), roads, streams, earthworks, archeological base map for Jamestown Island, 18th-century historic sites for Yorktown, historic glasshouse; grid overlays for UTMs, longitude/latitude, and park roads system kilometer markers; park boundaries, fee-simple acreage, scenic easements; fire management units; rare, threatened and endangered species. and critical habitats; wildlife sightings; historic vegetation changes
College of William and Mary–VIMS, Coastal Management and Policy Center	wetlands (expansion on NCSU work), additional streams, shorelines (1854 to 1990), near surface geology, flood plains, global positioning system (GPS) geodetic control points, watersheds and subwatersheds, Chesapeake Bay regulatory zoning, water quality and quantity data
State of Virginia, Council on the Environment, ECOMAP GIS	1972 DLG Roads, trails, political boundaries, shoreline, wetlands (NWI), streams, ponds, rivers
USNPS, Colonial National Historical Park	wildlife sightings, fire history, utility rights-of-way, legal jurisdiction, exotic and noxious vegetation species, vegetation species of special concern, expansion of fields, geomorphology of Jamestown Island, National Register of Historic Places, special events and emergency hazardous spills, soil sampling
SCS, Richmond, Virginia	soil survey, drainages
James City and York counties, GIS	(to be supplied in the coming year): topography, order-one geodetic control points, building outlines, adjacent tax parcels, adjacent land-use patterns

Cost and Funding

Developing a GIS system is costly and time-consuming. However, the benefits are great, allowing for responsive and enhanced park planning, environmental assessment, historical research, inventory and monitoring, and emergency response. Based on our experience, the full development of GIS can take a minimum of two years. The park must be able to dedicate one to one-and-a-half FTEs to accomplish full development, which is in addition to the time of interns and graduate students working on projects. The park GIS staff must be technically competent and well trained. They need an in-depth understanding of base operating systems, archiving, GIS software, hardware, and data-base management.

Funding for our GIS has come from a number of sources, including the USNPS Washington office and Mid-Atlantic regional office, park base funding, the state of Virginia, VIMS, and NCSU. Figure 2 summarizes expenditures since the winter of 1990.

Software

The choice of software will dictate staffing, hardware, and final database management system design. Colonial's GIS software choice is ATLAS*GIS, a DOS-based system. The choice of ATLAS*GIS was dictated by the low initial cost, user-friendly menu system, minimal training requirements, the capacity to perform the mapping analyses and production tasks identified in the workshop interviews, and conversion abilities to and from ARC/INFO, AUTOCAD, and DLG3. These data exchange capabilities are essential for the efficient transfer of data to and from non-USNPS sources. These include the Virginia Council on the Environment ECOMAP GIS, VIMS, and the counties of York and James City. Whatever the choice of software, it must have conversion capabilities so that data can be shared with all cooperators.

A PC-DOS software application allowed us to use the same hardware that was already in the park, and didn't require learning a new operating system such as UNIX. ATLAS*GIS has a database system that is fully compatible with dBase III plus and dBase IV. The software is supported at many universities, and has a macro-programming language, ATLAS*SCRIPT, for repetitive tasks, special applications, and customized programming. Also, ATLAS*GIS has a report-writing module built in that creates data tables (e.g., acreage reports). Finally, ATLAS*GIS has excellent map presentation output, supporting dot-matrix and laser printers, plotters, and raster printers. Linked with IDRISI, a low-cost raster PC-DOS system that can handle satellite images, we have a complete GIS system at less than one-half the cost of ARC/INFO, and more versatile than GRASS, with less training required.

Figure 2. GIS Expenditures at Colonial National Historical Park (as of 30 September 1992)	**COST**
HARDWARE, distributive system, 3 PCs, 2 plotters, 2 printers	$45,000
SOFTWARE, GIS, supporting software: ATLAS*GIS (2), LAN ATLAS*GIS (1), ATLAS*PRO (1), LANTASTIC LAN, QEMM, NORTON	$8,100
SALARY (personnel time spent for data development, administrative, planning)	$90,000
DATA INPUT, DEVELOPMENT, FREE THEMES from state of Virginia and VIMS	$153,000
TRAINING, travel, meetings	$5,500
SUPPLIES, materials, contracts for hardware maintenance	$2,900
SPECIAL PROJECTS	$10,500
TOTAL	$315,000

Hardware

The choice of software and system design will determine the final decision about hardware configuration and purchases. Options include stand-alone, multi-purpose, or network operation. Some key factors that are generic to all systems, and very important for effective operation, include virus protection, uninterrupted power supply, power conditioning, a back-up (archiving) system, and environmental control (ventilation, temperature, and humidity).

We recommend that the minimum DOS hardware configuration be 8 MB of RAM (12 MB if using WINDOWS), a 486-MHz processor, a 335-MB hard disk, a high-resolution video board matched to the GIS software drivers, and a 20-inch screen (select a high-quality monitor offering high resolution, a flat screen, adjustable color, and compatibility). Also, think seriously about buying a tower case configuration. This will provide plenty of additional slots for add-on boards to accommodate LAN, video, fax, extra hard-disk drivers, and CD-ROM.

Include a laser-jet printer and large-size plotter. The laser-jet printer should have 4-5 MB of memory to handle large data files. We often use the laser-jet printer to test map output design and for final file records of all maps produced.

We recommend a plotter which handles A-E sizes, and has carousels that hold eight pen colors. A top-of-the-line plotter ($7,000-8,000) provides the fastest and most accurate plotting. We chose a Hewlett-Packard Draftmaster because of its technical performance, as well as the company's outstanding technical support, and its responsive on-site repairs. The secondary GIS location at our park has a smaller A-B plotter. If funding were available, a raster (A/B size) base color printer would be a good investment, although not critical. With the advent of new colors for plotters, we will be able to create even more effective maps that closely reflect raster output.

When procuring a digitizer for corrections and smaller projects consider buying the higher resolution back-lit digitizer that can handle U.S. Geological Survey (USGS) 7.5-minute topographic quadrangle maps. The larger the digitizer, the better.

Regarding the health and safety of GIS operators, proper ergonomic furniture and adequate lighting is critical. Does the table have an adjustable-height keyboard with wrist pad and anti-static control strip? Is there proper lighting for the different work areas? Is the lighting adjustable? Does the lighting cause glare on the monitor screen? Finally, proper heating, air conditioning, humidity control, and dust control is critical for hardware operation, plotting, and printing. Also, secure sufficient floor space for map files, work tables, and digitizer.

In preparing a request for bidders, use companies that have the technical expertise to provide service during the first year and beyond. On-site warranty service during the first year is a wise investment. After the first year it's desirable to have, at a minimum, on-site warranty service for the plotter. Make sure the bid specifies that the vendor will guarantee hardware and software compatibility. As for choosing among EISA, ISA, SCSI configurations, make sure the vendor guarantees that all parts and boards are compatible. Early on we had problems with the high-resolution video board and tape back-up system not being fully compatible with EISA or SCSI architecture.

Theme Development

There are many sources available for development of your GIS themes. These include USGS, EROS, SCS, the U.S. Environmental Protection Agency, state and local governments, universities, and park maps. You may have to modify or derive separate themes from those sources. It may be necessary to know how the themes were developed including scale, accuracy, and protocol for classification. This also applies to anything that is developed from park maps, aerial photography, or satellite imagery.

It is imperative to decide how the theme is to be used and develop guidelines for classifying the data. How will the proposed software handle the data? This will definitely affect the final classification scheme. When we received 1:100000 DLG data from the state of Virginia, we found it was from 1972 and due to transportation errors it did not always properly align with our 1:24000 data. This required us to reformat the road delineation to meet our database needs.

Don't discount the importance of digitizing guidelines. How arcs, nodes, lines, points, and polygons are digitized will make a significant difference in the final quality and usefulness of the theme. Quality assurance protocols and error checking can reduce the number of slivers, unclosed polygons, or missing key nodes. Agencies such as SCS have written guidelines for developing themes, e.g., soil surveys (shoreline may be based on low, mean, or high tide). Will you digitize only the road center line or the shoulders or both. You should be able to use the final digitized product to calculate and conduct GIS operations by park boundary, project area, or political subdivision.

Identify what sort of geodetic control system is available in your area. Do you only have the USGS 7.5-minute maps available, or USGS benchmarks? Check on the availability of GPS order-one benchmarks provided by local or state government. The use of GPS, which was unavailable when we developed our earlier themes, can make a large difference in accuracy. A properly registered base map and themes are critical to GIS use. Another must is to decide on a base map for subsequent data theme development and registration. We used USGS orthophotoquadrangles but would have worked with a finer resolution had it been available.

A good test of the GIS is the development of a few important themes before full implementation. This allows for system testing, experimentation, and refinement. A lesson we learned from our earliest work in developing the vegetation cover data theme, is not to use any aerial photography that produces a negative or transparency smaller than 9x9 inches. Anything smaller makes interpretation very difficult. The choice of film types depends on the season and the type of data needed to record and interpret. Contact a remote sensing specialist for advice. You may need to photograph your area in different seasons or different types of film or both. Finally, don't forget the important phase of field-checking all your interpreted data. Develop a statistically valid method. In interpreting bottomland hardwoods from aerial photographs on Jamestown Island, we found sixteen polygons that were initially interpreted as upland hardwood because of the flat contour of the land. After "ground-truthing," they were changed to bottomland hardwoods. We also discovered missing streams and roads, and trails classified as roads, from USGS DLG files.

We don't recommend digitizing all of the themes in-park. For the initial theme development use a cooperator or one of the national contractors for manual digitizing or scanning. We have found it extremely useful and cost-effective to bring our cooperator into the park to develop and enter the different themes. Having the cooperators on-site allows them to work directly with the subject specialist during the input process. It might be the park historian, curator, park engineer, fire management officer, law enforcement specialist, or natural resource specialist. Moving the digitizer around to be near the subject specialist allows for questions to be answered quickly. Ambiguities with a source map can be quickly clarified and answered. It also allows for regular quality checks and corrections. Also, by doing the work on-site the initial standard operating procedures for the theme can be quickly updated. We have found this a more effective and accurate method than developing a series of mylar overlays and sending them out to be entered into the GIS off-site.

Database Management

In the operation of the GIS, data-base management is critical. This includes access to the database; who is permitted to edit data; and tracking (documenting) new additions, changes, and problems. Database management also includes security, back-up responsibilities, restoration after disasters, and archiving. One person must have ultimate responsibility for all database management. Access to the original database must be limited and careful tracking of all changes and additions are mandatory. A data dictionary for all coded information must be maintained. It is important to have a clear understanding of and documentation regarding the accuracy and resolution of each database theme.

Our standard operating procedures cover database development and quality control and assurance, digitizing, hard disk setup, LAN use, archiving, documentation, security, disaster preparedness and recovery, and maintenance of hardware. There are individual sections dealing with the different databases which explain structure, coding, file naming, primary and secondary naming (along with layer naming), and data sharing with cooperators.

Access to copy, edit, archive, and restore files should be restricted. Practice "safe computing"—always check new data for viruses and routinely check GIS hard disks.

Future

So where are we going with GIS at Colonial during the upcoming fiscal year? We hope to add in-park color scanning and digitizing capabilities (we borrow a unit now). We will be exploring digital orthophotoquadrangles and raster software for satellite imaging. We will further develop our adjacent land use, environmental, and cultural database themes. We hope to add WINDOWS capability to the GIS and explore linking it with digital photography of our resources as part of our inventory and monitoring program. This would include the use of a digital slide converter and camera. We will be converting our total GIS database to ARC/INFO for sharing with local and state government. The park's cultural database will greatly expand as part of the multi-year Jamestown Island archeological survey. We will be adding ATLAS*SCRIPT software for application development, and possibly CD-ROM backup capabilities to replace our present 700-MB tape backup. We will increase the processing speed of our main PC with the addition of an Intel 486 overdrive chip. We will be greatly expanding the data dictionary and expanding our attribute databases. We also need to expand our hard disk storage. We hope to add GPS equipment for inventory and monitoring work. We will continue to expand our training to upgrade skills. We also expect to add additional GIS users through training. We will continue our public relations efforts explaining GIS accomplishments to park staff, visitors, cooperators, and the community.

GIS is an extremely useful tool to manage the multitude of spatial and non-spatial data required for park management. We can expect a quantum leap in the size of our GIS databases as the park becomes more involved in long-term environmental monitoring. GIS provides a whole new perspective when park resource data is georeferenced, analyzed, and displayed on a monitor or map.

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