GIS Tools for Planning, Management, and Communication

by Robert D. Hewitt, P.E. and Rebecca B. Higgins, P.E.

Geographic information system (GIS) technology has evolved to the point where non-specialists can harness the power of GIS to facilitate master planning, guide operational management, and enhance communications at a college or university. This article describes current GIS technology and presents a variety of tools available to the facility manager and planner. The article illustrates the use of GIS tools to 1) increase the effectiveness of master planning, 2) improve the efficiency of operations management, 3) communicate with students, faculty, and public communities, and 4) create an educational tool. Case studies from Wellesley College, Harvard University, Massachusetts Institute of Technology, and Tufts University are presented to illustrate applications of GIS technology.

***Robb Hewitt is development associate for Trammell Crow Residential, Needham, Massachusetts, and can be reached at rhewitt@tcresidential.com; he formerly was a geotechnical engineer at Haley & Aldrich, Inc. Rebecca Higgins is staff engineer for Haley & Aldrich, Inc., Boston, Massachusetts; she can be reached at rhiggins@haleyaldrich.com. This is their first article for* Facilities Manager.**

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Introduction to GIS

A geographic information system (GIS) is a computerized database management system which can be used to capture, store, retrieve, manipulate, analyze, and display spatially-referenced information, otherwise known as *geospatial data.* A broad definition of geospatial data is a dataset that identifies the geographic location and characteristics of natural or manmade objects or features as these relate to a particular geographic region on earth. Since datasets can include a wide array of information such as physical, biological, cultural, demographic, or economic, they are valuable tools in the natural, social, medical, and engineering sciences, as well as in business, marketing, and planning (Mark *et al.*, 1996).

Example types of datasets that may be useful for implementing GIS applications at colleges and universities include:

- Aerial photographs
- Zoning data (e.g., residential buildings vs. classroom buildings)
- Building information (floor plans, building/classroom names, building heights)
- Roadways and bike/walking paths
- Emergency routes

- Utility information (types, locations, invert elevations)
- Subsurface information (geology, groundwater levels, areas of contamination)
- Underground storage tank locations and tank details
- Hazardous waste generation and collection locations
- Maintenance schedules of buildings, landscaping, and utilities

Typically, the relevant data are stored in one centralized database and displayed as different layers within a GIS. An advantage of using a centralized database linked to a GIS system is that various layers can be displayed at once, allowing for meaningful analysis in a user-friendly and efficient manner. For example, potential new building or utility corridor locations can be evaluated by overlaying potential locations with available information (e.g., existing utilities, soil conditions, utilities).

Implementation of GIS at Colleges and Universities

Given the power of modern personal computers and the internet, creating a GIS platform for an educational institution has become a less costly and achievable goal. Once the necessary hardware and software are acquired, available data is gathered to create base layers for the GIS platform. In addition to information specifically related to the college or university, there are numerous statewide and nationwide resources for GIS datalayers. For example, MassGIS (http://www.mass.gov/mgis/) is a website maintained by the Commonwealth of Massachusetts Executive Office of Environmental Affairs that provides free downloadable GIS datalayers such as roadways, water bodies, zoning, conservation/recreation areas, demographic data, and aerial photographs.

Once the basemaps have been created, facility-specific information such as campus building and classroom information, floor plans, utility plans, and geologic and hydrologic information can be compiled and added to the system. For hardcopy data in existing files, the information can either be scanned as images or the pertinent information can be entered manually into the database system with locational references (e.g., X and Y coordinates or latitude/longitude) to allow mapping of the data. If the image is a map, it can be scanned and georeferenced (using tools within GIS) to the same coordinate system as the base plan to allow the map to be overlaid with other layers.

Once the data and map layers are compiled into a GIS platform, the benefits of storing, manipulating, and retrieving data from the system for management and decision-making purposes soon overcome the cost of the data gathering efforts. A successfully implemented GIS system at a college or university can provide a variety of beneficial uses, which may include:

- Efficient data management, analysis, and visualization
- Enhanced master planning and decision making
- Effective operations management
- Educational tools for students
- Enhanced communication with students, faculty, and the public

The following sections further describe the benefits gained from implementing a GIS and are illustrated by recent examples of GIS use at colleges and universities.

Management, Analysis, and Visualization of Data

Over the years of storing paper data, some of the information may be lost, damaged, or destroyed. Fire and water damage can have devastating impacts on hard copy files. Having an electronic database of the information (with backup at an alternate location) provides better insurance against lost or missing data. Additionally, a vast amount of data compiled in one centralized system is more readily accessible than if the information is stored in file cabinets or on separate computer systems in different departments. Data can be accessed remotely and can be used by many users at the same time. As additional data becomes available, the database can be easily updated. Both historic and newly acquired electronic data can be readily combined and utilized by multiple personnel to allow better analysis and visualization of spatial data.

The following two examples illustrate GIS and database applications for management and evaluation of groundwater quality and geologic information.

Groundwater Quality and GIS—Wellesley College

Wellesley College recently conducted a substantial construction and remediation project to revitalize a 20-acre parcel of land impacted by environmental contamination. The contamination was the result of the manufacturing process by the former parcel owners. To monitor the effectiveness of the remediation, a quarterly groundwater testing program is conducted from a network of 75 monitoring wells located across the 20-acre site. Data are collected in the field and imported to a database to store the sampling information and test data. The data are analyzed and presented spatially using GIS applications to investigate spatial variation across the site, evaluate changes since previous readings, monitor changes in groundwater flow direction, and identify the impact of off-site sources of contamination.

Figure 1 illustrates the use of GIS to analyze and display groundwater flow and potential contaminant migration pathways from the contaminant source across a portion of the campus.

Geologic Information and GIS—Tufts University

Research conducted at Tufts University involved the use of a GIS and database system to investigate the spatial relationship among geologic data across a 2.5-square mile study area in Cambridge, Massachusetts (Baise and Higgins, 2003). The study area is shown in Figure 2. The project entailed compiling approximately 1,000 hard copy logs of subsurface explorations including 7,200 geologic samples gathered from over 70 years of exploration programs. The study area in which

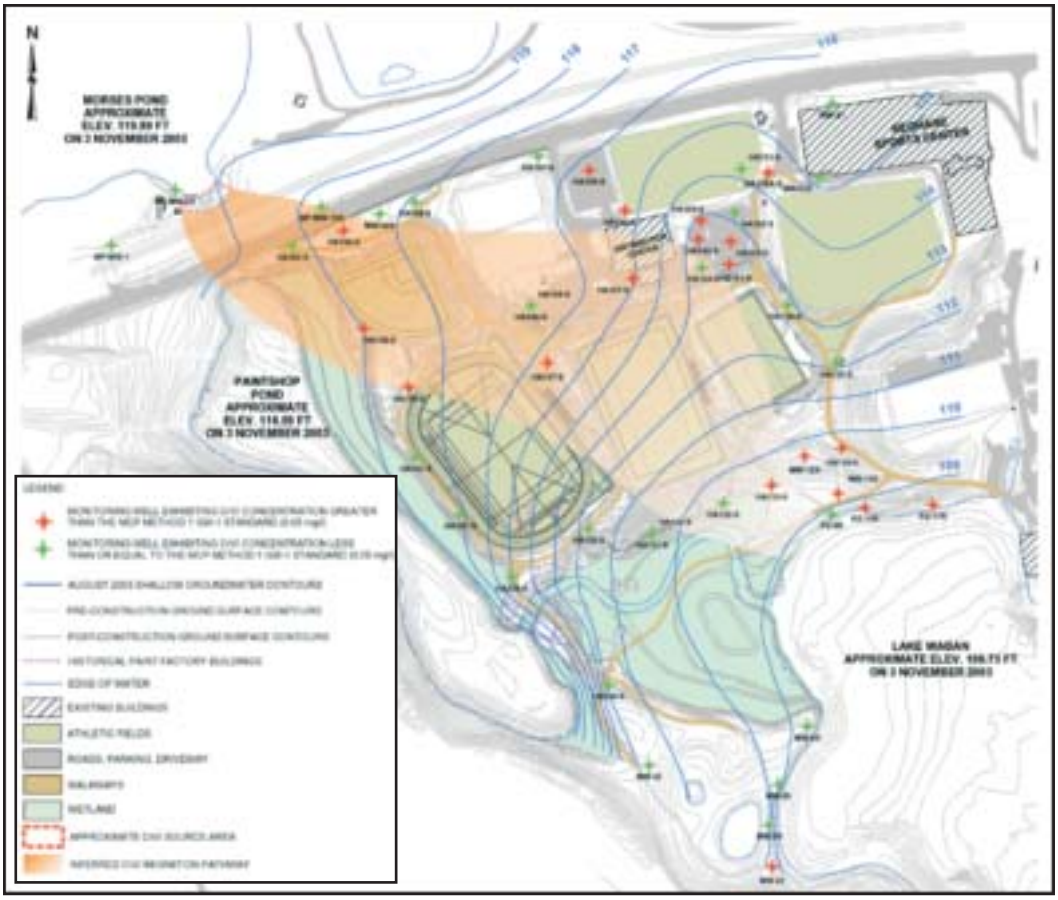


Figure 1
Use of GIS to Display Potential Contaminant Migration Pathway—Wellesley College

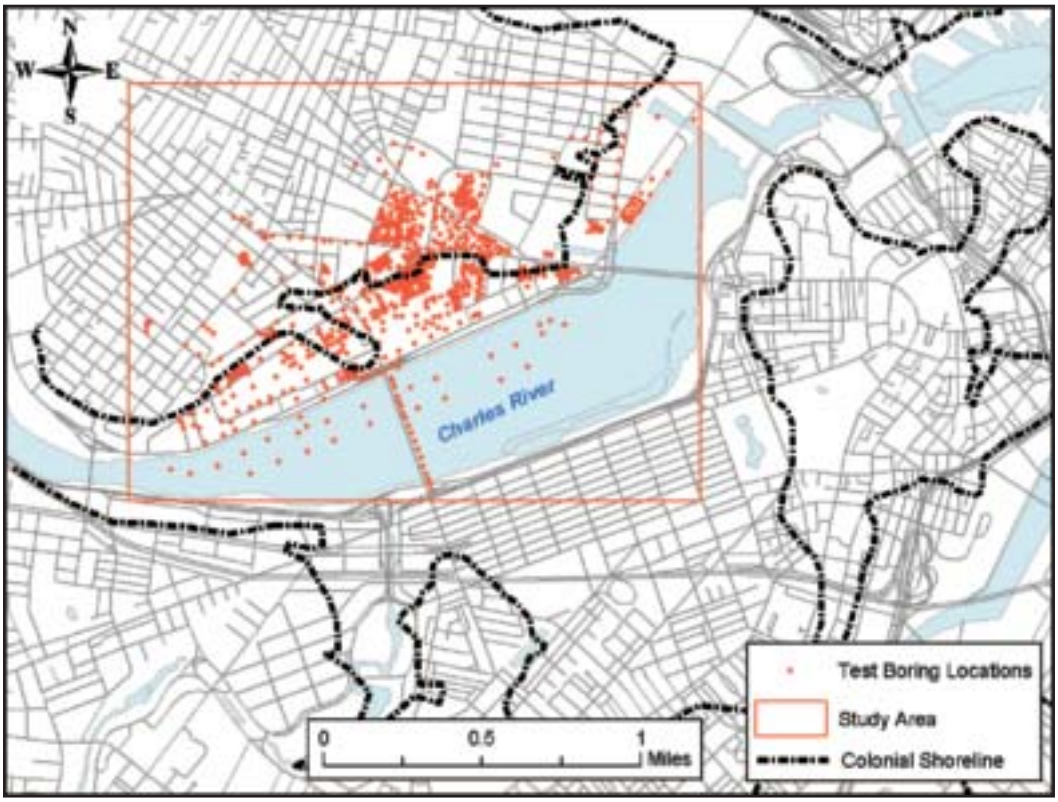
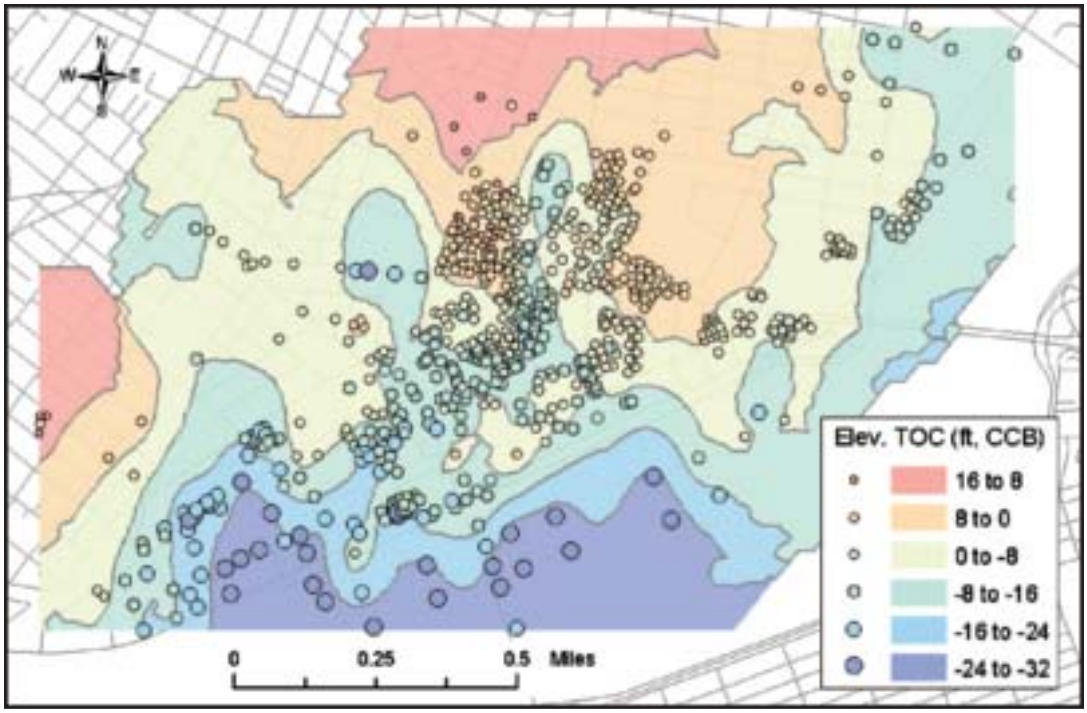


Figure 2
Study Area and Subsurface Data Points for Research Conducted at Tufts University

Figure 3
Elevation of Top of Marine Clay Stratum (Higgins and Baise, 2003)



these were conducted included the campus of the Massachusetts Institute of Technology (MIT), in Cambridge, Massachusetts. The subsurface information included on the exploration logs was entered into a relational database and displayed and analyzed using GIS. The information was then analyzed using geostatistical tools within the GIS software in order to interpolate "continuous" geologic surfaces across the study area.

One stratigraphic unit explored during the research was the marine clay deposit, known locally as the Boston Blue Clay, which underlies the region. Due to the complex depositional environment adjacent to the Charles River, the surface and the thickness of the clay deposit varies significantly across the region. Figure 3 shows an interpolated map generated from tools in GIS showing the top of the marine clay layer across the campus based on the information compiled in the database. The map indicates that the top of the clay deposit slopes downward toward the Charles River, varying by almost 50 feet over approximately one mile. Tufts University used the GIS to assess the spatial variability of different geologic units and to study potential liquefaction hazards associated with natural sand deposits.

Tools for Master Planning

While the examples discussed above were conducted for research purposes, the compilation of subsurface information over a campus-wide area also can be extremely useful for master planning purposes. Subsurface information can be used to evaluate potential foundation conditions, as well as to identify areas to avoid due to premium construction costs. For example, the depth and thickness of the clay deposit in the Boston area is critical to selecting the foundation types (shallow vs. deep foundations) for new buildings, as well as for evaluating potential building settlement. These issues can have significant cost impacts to the project and should be carefully considered when selecting a potential building site.

In addition to cost premiums associated with foundation selection, soil and groundwater contamination also play an important role in identifying cost premiums associated with proposed development areas, particularly for campuses located in urban areas or on filled land where contamination is more likely. Chemical contamination information can be incorporated into the database system to identify development sites where costs for remediation may be higher than other areas of campus.

Furthermore, the compilation of available subsurface information collected from previous campus developments into one system enables the identification of areas where additional subsurface information may or may not be required. Since the spatial data could be presented showing locations of previously performed investigations over a large time period, future field programs for new structures and utilities could better use the available information and thereby reduce the costs associated with field geotechnical and environmental characterization programs.

The following examples from Wellesley College and Harvard University illustrate how GIS is being used for evaluating potential sites for new buildings and master planning purposes.

Wang Campus Center—Wellesley College

GIS was used by Wellesley College as a tool for siting studies for the new Wang Campus Center and Davis Parking Garage (intended to consolidate existing parking areas and promote a "walking campus"). The college used GIS to pro-

Figure 4
Use of GIS for Master Planning Activities at Harvard University

vide preliminary feasibility evaluations of proposed building locations. GIS was utilized to provide a cost-effective evaluation of subsurface soil and groundwater conditions; existing elevation contours; and proximity to college roadways, utilities, and residential buildings. The GIS helped to identify an area that suited the needs of the college; however, GIS data showed that the selected site included areas of known contamination that would add significant costs to the construction project.

After careful analysis of the costs and benefits of the site, this location was selected; however, the early identification of costs associated with soil remediation allowed for accurate budgets to be established for the project. GIS was then used to develop a design at the chosen site that evaluated excavation and reuse scenarios to minimize costs associated with off-site disposal of soil. The portion of the projects associated with management of environmental contamination came in below budget, due largely to the GIS planning undertaken prior to construction.

Master Planning Allston Campus—Harvard University

Another example of the use of GIS for master planning is the growth and extension of Harvard University into the Allston, Massuchusetts area. The Harvard Planning and Allston Initiative (HPAI) was formed to create the framework for the new development in a way that best supports Harvard's academic mission and growth needs while ensuring that the new campus is an integral part of the broader urban community (www.allston.harvard.edu/ai.htm). Figure 4 illustrates the use of GIS as one of the many tools that HPAI uses to aid in the planning and development of the 344-acre parcel of land.

Tools for Facility Management and Operations

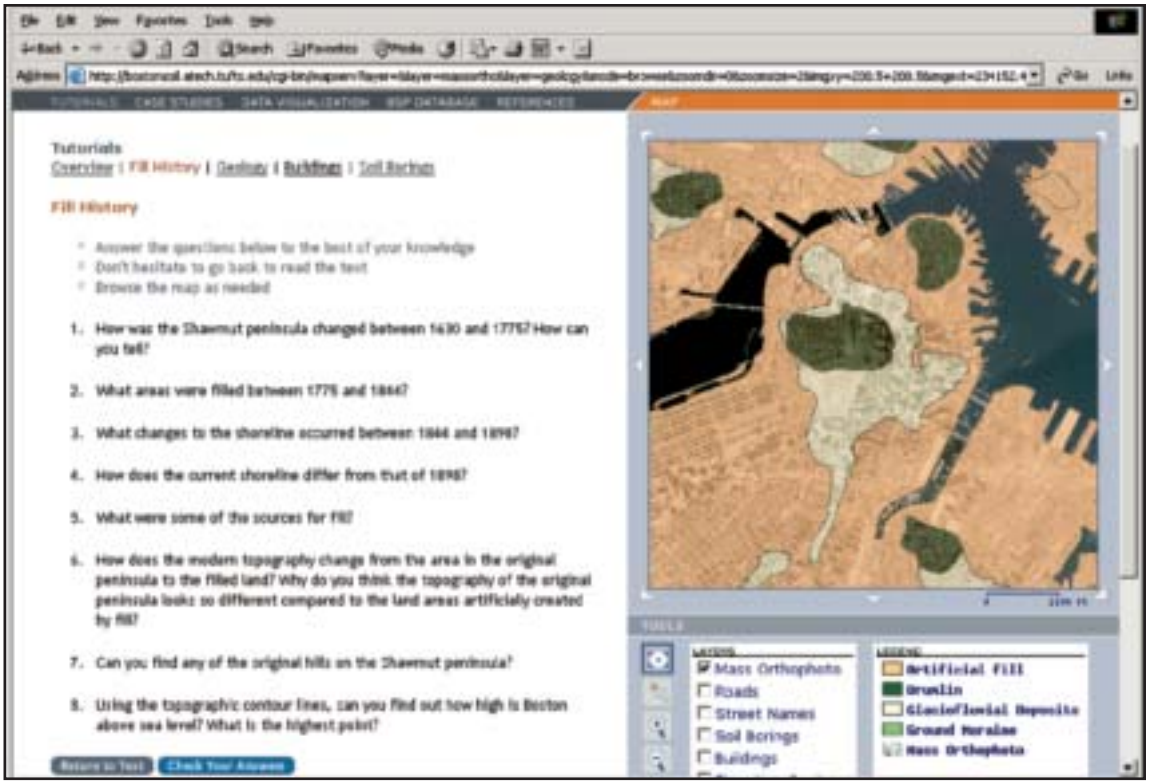
Since GIS can be used to store and display data spatially, GIS is well-suited for management of campus facility operations. GIS tools for facility management can be used to efficiently schedule maintenance activities for buildings, utilities, roadways, and landscaping features by evaluating areas spatially. In addition, creating GIS layers for landscaping features can be used for master planning landscape improvements. For example, a layer showing oak trees on campus could display the location, current dimensions, age, and date of last pruning. There are tools in GIS that could be used to simulate what the mature landscaping will look like or how the site will change seasonally.

Other GIS applications include management of underground storage tanks and permits, and the evaluation of potential nearby impacts of leaking tanks. Environmental health and safety management operations such as indexing locations of hazardous waste storage and generation, areas designated for recycling operations, emergency vehicle access routes, and evacuation plans are ideally tracked using GIS tools.

GIS as an Educational Tool

GIS can be used as an educational tool to teach students about mapping, interpolation techniques, and geology. Under the direction of Professor Laurie Baise at Tufts University, an interactive GIS website has been established to aid students in exploring geologic conditions in Boston. The database was developed using available subsurface information such as data from the Central/Artery Tunnel project. Tutorials included on the website (Figure 5) teach students about the filling history of Boston, geologic sampling techniques, and foundation con-

Figure 5
Use of GIS in the classroom as an educational tool, Tufts University



siderations for buildings based on varying subsurface conditions. The website was developed in 2004 and is being implemented in graduate and undergraduate courses within the Civil Engineering and Geology Departments. (Boston Subsurface Project Website: http://bostonsoil.atech.tufts.edu/index.html)

Tools for Communication and Marketing

Applications for communication and collaboration using GIS are just emerging at universities and colleges. GIS is being used for a wide variety of other functions important to educational institutions, including:

- Mapping space utilization for research grants and federal funding applications;
- Communicating campus activities and facility schedules with the university public (faculty/staff, students, community) using GIS to display information at campus buildings via the Internet;
- Providing interactive campus maps, accessible through the Internet, showing parking areas, walking paths, bus routes, class locations, and faculty offices. For example, students at MIT developed a GIS system that tracks campus bus movements and provides up-to-date locations via the Internet, so that minimal time is spent waiting for the bus (http://shuttletrack.mit.edu);
- Using GIS Web interfaces as a differentiator to help attract faculty and students;
- Communicating information on campus improvements and ongoing construction projects; and
- Increasing communication and effectiveness between facility managers and consultants during planning, design, and construction.

Conclusions—The Future of GIS

Technology has greatly improved so that GIS and other related tools can be readily used by facility managers, planners, faculty, and students at educational institutions. Since new data will be electronic, incorporating existing hard copy data into an electronic platform will allow increasingly more efficient planning, operations, and communication at educational institutions. GIS is an economical, beneficial tool that can be effectively used for planning by colleges and universities, regardless of the size of their endowment. As the technology continues to advance, the usefulness of GIS will continue to expand and improve.

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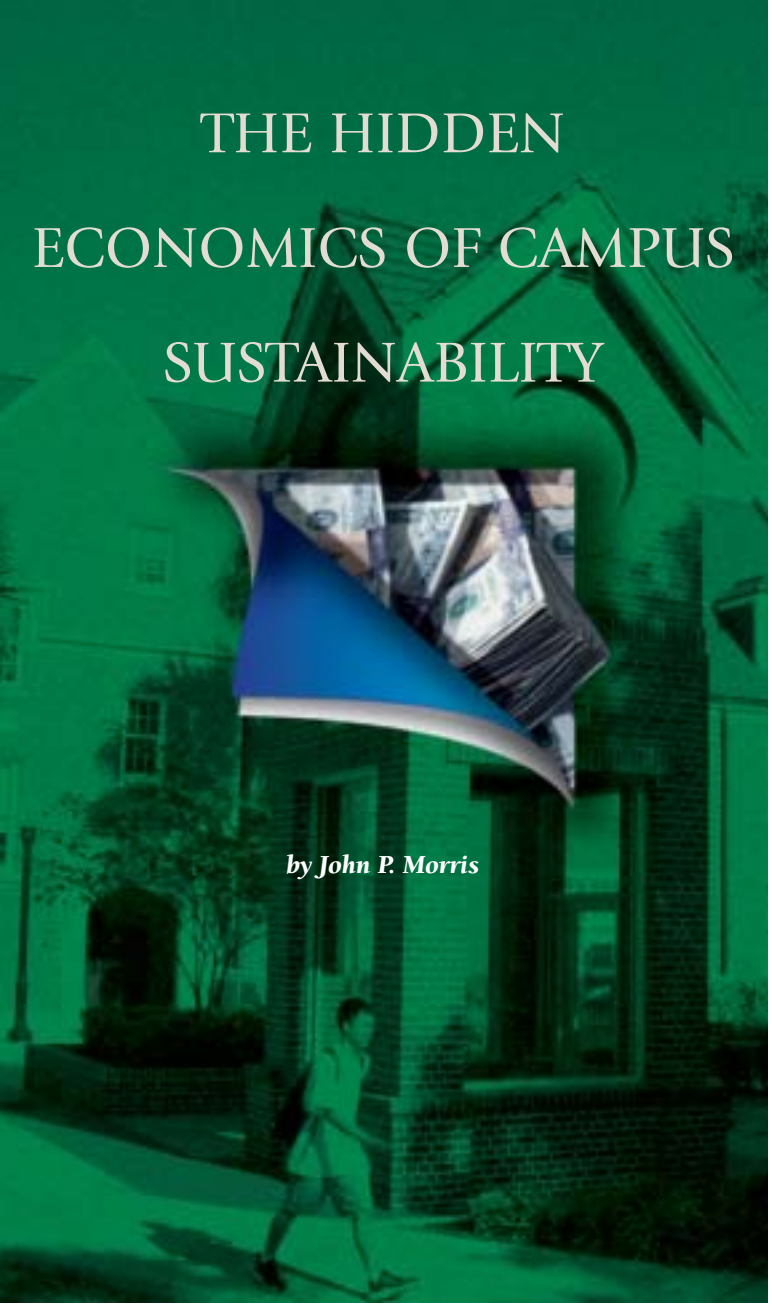
THE HIDDEN ECONOMICS OF CAMPUS SUSTAINABILITY



by John P. Morris

As the manager of facilities operations at Colorado State University (CSU) I had the opportunity to lead a variety of work units including Utility Services, Energy Management and Water Conservation, Trades Services, Custodial Services, Trash and Recycling, Outdoor Services (Grounds), and Transportation Services. Each of these work units has actively implemented numerous sustainability programs. However, the purpose of this article is to discuss some of the less obvious benefits of campus sustainability efforts that are often overlooked.

***John Morris was until recently the manager of facilities operations at Colorado State University, and is now physical plant director at the University of Colorado, Boulder. He can be reached at john.morris@colorado.edu. This is his first feature for* Facilities Manager.**

Most of us are familiar with the obvious economic and environmental benefits associated with utility cost avoidance programs. For example, Colorado State University has actively encouraged energy management and water conservation efforts since the early 1970s. Since the mid 1980s, CSU has had a utility cost avoidance of over $35 million. Associated with these programs is an estimated emissions avoidance of over 1 billion pounds of carbon dioxide (CO_2), over 6 million pounds of sulfur dioxide (SO_2) and over 3 million pounds of nitrous oxide (NOX). However, some of the less obvious benefits of these efforts include the avoidance of expensive utility plant investment fees; emission equipment installations or upgrades, utility infrastructure upgrades; maintenance savings; improvement in the quality of the indoor environment; free publicity; and a recruiting tool.

Utility Plant Investment Fees

CSU's conservation efforts have delayed and deferred the need to purchase expensive plant investment fees from the local utility supplier. For example, since 1990, the student population has increased by 5,000 students (a 25 percent increase) and building square footage has increased nearly 1.4-million gross square feet (a 19 percent increase), while potable water use has decreased over 108-million gallons (a 22 percent decrease). The equivalent cost of water and wastewater plant investment fees is in excess of $2 million.

Emission Equipment Installations or Upgrades

The university is required to have air emission permits under Title V of the *Clean Air Act*, which imposes limits on the quantity of specific emissions. Growth due to campus expansion could potentially require the university to incur the capital cost of implementing best management practices to control emission levels. Reducing the current emission levels through conservation efforts defers or potentially eliminates the need to invest the capital required to implement additional emission reduction best management practices.

Utility Infrastructure Upgrades

Conservation efforts have also deferred for decades the need to increase the capacity of expensive utility infrastructures. During the late 1980s, a major sanitary wastewater line experienced surcharge problems. As can be expected, a sanitary line that raises a manhole cover and overflows onto the campus is not a desirable situation. The cost to increase the capacity of this sanitary system is well over $2 million. The reduction in campus water consumption has not only eliminated the surcharge problem, it has also deferred the need to invest the capital required to increase the size of this system, even with the addition of several new buildings.

CSU also has a steam district heating system with three main boilers. Again, in the late 1980s, the university steam demand was quickly approaching the firm capacity of the boilers. Energy conservation measures have delayed the need to upsize the plant capacity for nearly 20 years, even with the